THE UNIVERSITY OF ALBERTA

THE MICROBIOLOGY OF ALBERTA PEAT BOGS

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "The Microbiology of Alberta Peat Bogs" submitted by Penelope Janet Gardner, B.Sc., Dip. Ag. (Soil Science) in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

Certain organic soils have been characterised pedologically, botanically and microbiologically.

Specific associations of mosses and higher plants were found to occur on different types of peat bogs. The seral succession of these plant associations is directly related to the development of the particular peat profile. As a result of studies on the vegetation and physical and chemical properties of these peats, modifications to the present classification of Canadian peat bogs have been made, resulting in a primary grouping based on the dominant vegetation.

The distribution of psychrophilic, mesophilic and thermophilic micro-organisms down the peat profiles was investigated in detail and differences in numbers and patterns noted for the different peat types. Certain genera, notably the Chromobacteria and the Cytophagae were found to be much more abundant in well-decomposed Humisols. Ammonifying bacteria were present in large numbers, especially in the more humified layers. Some denitrifiers were found, but bacteria effecting other nitrogen transformations were absent. Iron-reducing bacteria were much more common than in mineral A horizons.

Certain similarities with more southerly peat bogs in North America were noted, however the effect of frigid temperatures was to significantly lower the microbiological numbers and activities.

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INTRODUCTION

The Myxobacterales are known to be abundant in wet areas. This investigation was undertaken to discover more about the natural conditions in which they live, and to attempt to understand the complex, specialised peat habitat.

Little biological study has been attempted on the vast Canadian "muskeg", although limited work on the larger members of the biota is available. The important botanical work of E. H. Moss on Alberta marsh and bog communities includes a detailed flora, specialised habitat lists, and elucidation of the seral succession. A few specialised microbial studies of Canadian "muskeg" have been made, for example Roberge and Knowles have recently reported on the ureolytic microbial population of a Quebec Black Spruce humus. However, nothing is known about the microbiology of Alberta peats. This investigation of the general microflora, including enumerative and physiological work on bacteria, actinomycetes, fungi and algae, together with detailed soil analyses and vegetation descriptions, was carried out on three significantly different peat bogs in Alberta, with the following aims:

1. To determine the type and number of myxobacters present and their relationships with the rest of the microflora.

2. To determine the inter-relationships of microflora, soil type and vegetation.

3. To determine variations in numbers and types of myxobacters and other microflora with humification, depth, season, etc.

4. To investigate the microbiological activity of the nitrogen cycle in peat bogs.

5. To estimate numbers of iron-reducing bacteria in peats.

6. To study the occurrence and classification of Chromobacterium species isolated from certain peats.

A national classification of organic soils is currently being prepared, and the present study created an opportunity to assess the workability of the most recent attempt.

As there has been no previous general microfloristic investigation, I employed a wide range of methods and media in order to determine those most useful for this type of study.

REVIEW OF LITERATURE

Introduction

Early Dutch naturalists claimed that a peat bog was a living, growing organism, and that the surface vegetation merely grew upon its dead outer skin! By 1652 an attempt was being made to classify Irish bogs, and in 1885 the first description of the development of a peat bog was published. (Gorham, 1957)

One of the more influential early workers in peat studies was van Post (1926). He stated that the following points must be considered in studying and classifying organic soils:

1. Definition of both macro- and microbotanical properties.
2. Degree of wetness during formation.
3. Nutrients available to plants growing in peat bogs.
4. Nature of decomposition processes.
5. Deposition of peat, formed in place or transported in.
6. Structural properties.

The sequence of botanical forms in the ecological series has been known for a long time for European bogs, (Gorham 1957, Pearsall 1960), but very little detailed work has been attempted in Canada. The work of Lewis and Dowding (1926), Lewis, Dowding and Moss (1928), and the later papers by Moss (1953, 1955) form the basis for ecological work on all Alberta muskeg.

The general term 'muskeg' includes both Peat Bog, characterised by conifers, ericads, peat-forming mosses (commonly Sphagnum), and a cushion-like substratum of raw peat, and the later sere, Bog Forest, in which the coniferous trees have become dominant. The Peat Bog

develops from a Reed or a Tamarack Swamp, these being very wet, marshy areas, the latter wooded (Moss 1953).

The initiation of a marshland community is based primarily on an excess of water, due to impedance by some geological, pedological or biological factor, such as a rock fall, a hard-pan or a beaver dam. A high rainfall leaches away plant and microbial nutrients such that only a few tolerant species may grow. Reeds colonise the shores of such ponds, and these are followed by the sedge sere or carecetum. Sphagnum moss now takes over, and the acidity caused by the decay of plant matter in water, and the anaerobic conditions reduce microbial activity so that deep deposits of Sphagnum peat are built up. This peat is termed an organic soil, but below about 60 cms. it may be regarded geologically as an organogenic rock. As drier conditions prevail on the now ombrogenous (atmospherically nourished, in contrast to ground-nourished, Sukachev 1926) sphagnic mass, ericaceous shrubs and later, conifers notably the black spruce, come into the succession. Hence the vertical succession parallels the horizontal zonation in the marsh-muskeg ecosystem (Gorham 1957).

Extent of Muskeg

There are about 112 million hectares of various types of peat bogs distributed throughout the world, mostly in the northern temperate zone, and particularly in glaciated areas.

Distribution of peat by continents

(Nikonov and Sluka 1964)

Continent	Area of peat bogs mills of hectares	Peat reserves bills of metric tons	Proportion of area covered by peat (%)
Europe	39.8	88.0	4.0
Asia	48.2	113.8	1.0
North America	15.9	32.7	0.6
South America	2.5	4.8	0.13
Africa	5.4	11.2	0.18
Australia	0.4	0.9	0.04
Total	112.2	251.4	0.8

Five countries contain 90% of these reserves, the U.S.S.R. and Canada being predominant:

Distribution of peat by countries

(Nikonov and Sluka 1964)

Country	Area of peat bogs mills of hectares	Peat reserves bills of metric tons	Proportion of area covered by peat (%)
U.S.S.R.	71.5	158.0	3.2
Canada	10.0	24.0	1.0
Finland	7.0	15.0	19.0
U.S.A.	5.2	14.0	0.7
Sweden	5.0	9.0	7.5

Other authorities variously estimate the peatlands of Canada as occupying up to 10% of the total land mass; in any case the peat bog area cannot be ignored.

Yet surprisingly little is known about the peat bogs of Canada. The McMaster University Muskeg Laboratory was recently set up to deal mainly with problems of productivity, trafficability, construction and foundation engineering. The soil scientists are just beginning to tackle the classification of these organic types. As already mentioned, the vegetation has been well-documented for a number of areas in Alberta, but extremely few microbiological studies have been made on Canadian peats, with none at all in Alberta.

Soils

In Alberta organic soils are defined as having an accumulation of sedge or moss peat greater than 30 cm. deep. The sedge and moss peats are not separated for mapping purposes in most areas, although they are different chemically. Sedge has a pH range of 6.0 to 7.0, about 3.0% nitrogen and a high calcium saturation whereas moss is described as having pH 4.5 to 5.5, less than 1.0% nitrogen and a high exchangeable acidity (Bowser *et al*. 1962). In a few areas the sedge-grass peats are distinguished from the *Sphagnum*-black spruce type (Lindsay pers. comm.). Presently a new detailed classification of organic soils is being tested, (Wicklund 1963, Ehrlich 1965, Odynsky 1966-7 pers. comm.).

Flora

Moss (1955) admirably summarized the current knowledge of the flora and floristic succession of Alberta bogs and bog forests. The pioneer work of Lewis and Dowding (1926) dealt with the structure, vegetation, peat and history of small muskeg areas in the vicinity of

Edmonton. These bogs have been formed on glacial-lacustrine clay in small basins in morainic areas, and are characterised by Sphagnum moss, with Labrador tea (Ledum groenlandicum) as the leading shrub, and black spruce (Picea mariana) as the dominant tree. Sphagnum is tending to disappear, being replaced by vegetation indicative of drier conditions, these caused partly by fires. They also report retrogression due to inflow of springs highly charged with mineral water, to form calcareous lakes in a peat basin.

Picea mariana associations

Black spruce forests have a number of phases, and intergrade naturally with other vegetation types. Two main kinds of this forest are recognised in northern Alberta:

(a) Black spruce-feathermoss association, which intergrades locally with the white spruce association,

(b) Black spruce-Sphagnum association, which is regarded as a sub-climax stage of a Sphagnum bog sere.

Moss (1953b) concludes that differences in floristic composition, internal structure, origin and development occur.

The black spruce-feathermoss (Picea mariana-Hylocomium splendens) association often contains white spruce, aspen and willows. The associated herbs include Ledum groenlandicum, Vaccinium vitis-idaea var. minus, Rosa spp, Ribes spp, Equisetum spp, Cornus canadensis, Petasites palmatus, Limnaea borealis var. americana, Mitella nuda, Rubus pubescens and Carex spp. The floor is carpeted with "feather" mosses, and lichens (Peltigera aphthosa, Cladonia spp) are common. Usually this association develops in a shallow depression through sedge-grass-willow stages and without much

peat formation. The flora is similar to the "mature bog forest" described for central Alberta by Lewis et al. (1928) and somewhat like the dry phase of the bog forest reported by Raup (1946) for northeastern Alberta. Moss suggests that this black spruce-feathermoss association may be interpreted as an edaphic climax, maintained by poor drainage and periodic burning, perhaps for long periods.

The black spruce-peat moss (Picea mariana-Sphagnum) association includes some tamarack, paper birch and certain willows. The chief flowering plants are the nearly continuous cover of Ledum groenlandicum, with Vaccinium vitis-idaea var. minus, Rubus chamaemorus and Smilacina trifolia. The uneven floor of Sphagnum mounds with other bog mosses and Cladonia spp is characteristic. This association has arisen in depressions through acid bog stages and with the production of a considerable thickness of Sphagnum peat. It is interpreted by Moss as a subclimax community, maintained by soil conditions and periodic burning, which prevent the natural succession to a black spruce-feathermoss community. The "young bog forest" reported by Lewis et al. (1928) for central Alberta, and the wet phase of the bog forest described by Raup (1946) for the Athabasca-Great Slave Lake region are essentially similar to the black spruce-Sphagnum association.

Drepanocladus-Carex and Sphagnum bogs

There are various kinds of open bogs with sparse tree cover. Moss categorises:

"(a) Drepanocladus-Carex bogs, formed in basins from aquatic vegetation and marsh, and leading through bog-willow and bog-birch stages to a Larix laricina association, or through various stages to Sphagnum-Ledum-Picea vegetation.

(b) Sphagnum bogs developed as just indicated, or from aquatic-marsh vegetation without the interpolation of marked Drepanocladus or shrub phases. The latter mode of succession to Sphagnum bog has probably been the chief mode of bog development in Alberta, especially northward." Open bogs tend to progress to bog forest (Picea mariana-Sphagnum). On burning, a bog forest will retrogress to an earlier stage of the bog sere, and certain open bogs represent these disclimax conditions. Repeated burning of relatively mature Sphagnum bogs often produces a more or less stable open bog, the Ledum moor of Lewis et al. (1928) characterised by scattered black spruce, paper birch and willows, Labrador tea, Eriophorum spissum, Vaccinium and Oxycoccus species, Polytrichum, Cladonia, and low mounds of Sphagnum fuscum.

Sphagnum succession and the regeneration cycle

Marion Moss (1949) and Moss (1953b) have discussed the ecological relationships of Sphagnum species. "In terms of the dominant sphagnums, succession from the early aquatic condition, through intermediate stages, to the final "xeric" stage may be shown as follows: Sphagnum subsecundum (or S. teres) → S. recurvum → S. magellanicum → S. capillaceum → S. fuscum." This sere can be easily seen in large wet depressions of bogs, or where Sphagnum is advancing upon marsh or Drepanocladus bog.

The "Regeneration Complex" described by various European workers (Tansley 1939, Chater 1962-3 pers. comm.) was discussed by Moss (1953b) in relation to Alberta bogs. The growing Sphagnum bog consists of hummocks covered by the more xerophilous species of the sere, and hollows occupied by relatively hygrophilous species. The cyclic development

means that hollows gradually build up an ombrogenous association and become mounds, so that the former mounds become the sites of hollows, through a series of Sphagnum sequences. A section through such a peat shows a lenticular succession of peat moss remains. This state of dynamic equilibrium is naturally followed by a static equilibrium when ombrogeny eventually produces a bog surface too dry for any of the sphagnums except S. fuscum. It is significant that apart from the absence of strictly aquatic species, the "Regeneration Complex" shows the same Sphagna sequence as in the Sphagnum sere.

Chemical aspects

Considering the British bog succession Gorham (1957) observed that chemical changes are most marked when the bog growth becomes ombrogenous, that is, when all its moisture is derived from the slightly acidic precipitation. This contrasts with the earlier part of the sere where the water "feeding" the bog had passed through mineral soil and therefore picked up much Ca and Mg bicarbonate etc. and was hence not too acid. In Britain this would mean a pH higher than 4.5, whereas ombrogenous bog water is usually of a pH less than 4.2, and at dry periods even below 3.0.

Organic sulphur compounds present in the peat are converted microbially to H_2S and may be oxidised to sulphuric acid within the peat. There may be an exchange of hydrogen ions for metal cations which are adsorbed onto peat colloids, and thus the H^+ is free in the solution. H_2SO_4 is the primary cause of acidity of British peat bogs, colloidal and organic acids are abundant but probably only slightly dissociated compared with the strong mineral acid (Gorham 1957).

Ca, Mg, K and Na are the most frequently adsorbed cations, although Fe and Mn often accumulate in peats, for example forming Bog Iron Ore. Silicates are rare in ombrogenous peats, hence restricting the development of diatoms which possess siliceous frustules. Ombrogenous areas are often very deficient in many micronutrients, thus the flora is restricted to tolerant species having a low mineral content. These are probably not so much adapted to exist without these nutrients as being able to withstand a nutrient scarcity, and thus through lack of competition they become the dominant flora. If protected from excessive competition, many of these plants can be found in richer habitats where they grow much more luxuriantly.

Methodology

A comprehensive review of techniques for observation and isolation of soil micro-organisms was published by Durbin (1961), and information on techniques and ecology of soil fungi will be found in the book edited by Parkinson and Waid (1960).

Bacteria

The equilibrium between various groups of organisms existing in any environment at any given time will largely depend upon the availability of nutrients required for growth by these organisms. Special antagonisms and the presence of toxic factors may distort this relationship, but nevertheless the requirement of, for example, a special growth factor limits the development of certain species. By classifying bacteria according to certain nutritional needs, West and Lochhead (1940) suggested a method for measuring the bacterial equilibrium in soil. Lochhead and Chase (1943) examined the nutritional requirements of soil

bacteria more extensively. Seven main nutritional groups were recognised, ranging from organisms exhibiting their maximum development in a simple glucose and salts medium, to types unable to develop with supplements of amino acids, growth factors or yeast extract, but which require soil extract for growth. As this seemed a sensible mode of approach to peat bacteria, a similar type of nutritional experiment was attempted in the present study.

As it was found by Lochhead and Thaxton (1952) that vitamin B12 could replace many of the growth factors essential for some bacteria, a medium containing vitamin B12 was used in this study.

Taylor (1951) suggested some modifications, notably the use of rich selective media instead of the indefinite soil extract; a calcium-free basal salts medium instead of that including $CaCl_2$; and substitution of diammonium phosphate for potassium nitrate as the inorganic nitrogen source. Stevenson and Rouatt (1953) found that Taylor's criticisms were unjustified, and his modifications, if anything, lowered the effectiveness of the study.

Concerning the preparation of soil extract media, it seems obvious that extracts made from different soils will have different abilities to provide nutrients for bacteria. Various workers have attempted to amend soil extract to increase its effectivity. Among these were Lochhead and Chase (1943), who variously fractionated it and concluded that several growth factors affecting different micro-organisms were present in soil extract fractions. James (1958) carried out experiments on preparation and subsequent efficiency and cleared up some fallacies. He concluded that it is better not to dilute soil

extract after preparation; $CaSO_4$ and $CaCO_3$ added as precipitants have no effect on the clarity, or numbers of bacteria produced; a heated extract is better than one prepared cold; a fresh extract is more effective than a dried preparation; and that the addition of 0.02% dipotassium acid phosphate greatly increased counts. He also found that the variation between the numbers of organisms found using ten different soils for extracts, was no more than that between replicates from one soil.

Actinomycetes

Various media have been suggested for the enumeration and cultivation of actinomycetes. Konev (1962) recommended Czapek's medium with sucrose or starch, starch ammonia, and potato agar. Kudrina et al. (1964) suggested a gauze-starch salts medium, a glucose salts medium, and oat agar, whilst Agre (1964) advocates a peptone-corn-starch one. Küster and Locci (1963) investigated thermophilic actinomycetes in peat using a Beef-stock agar.

Waksman (1950, 1959) suggested egg albumen agar for plate culture of actinomycetes, and this was modified by Corke and Chase (1956) by the addition of the antibiotic cyclohexamide (Acti-dione) at 40 μgm/ml of medium, to restrict the size of the numerous fungi that are also able to grow on egg albumen agar. One hundred percent of their cultures grew well on the modified medium, so inhibition of actinomycetes was not suspected. As Waksman's egg albumen medium (without antibiotic) has been most widely used, and thus could afford comparisons, it was used in this study.

Fungi

The dilution plate method is by far the most commonly used way of estimating soil fungi. However, hyphae tend to remain with the heavier particles in a suspension or on sieving of the soil through 50μ pores. A microscopic examination of the residue enables hyphae to be picked out manually and subcultured (Warcup 1955). This is a very tedious, time-consuming labour and has been reported as distinctly unreliable (Parkinson 1966 pers. comm.), owing to the fact that the human eye cannot distinguish certain types of fungal filaments under the microscope. It was therefore decided not to attempt this method.

Soil plates, as used by Chesters and Thornton (1956), Sewell (1959), Kendrick (1962) etc., are intended to encourage the growth of fungi embedded in humus and attached to mineral particles, therefore different species may be isolated than by the dilution method, but hyphae present in the soil still rarely develop (Warcup 1950). The minute quantities of soil required (0.005 - 0.015 g per plate) are difficult to weigh out accurately and thus render this method unsuitable for enumeration.

Mycelial proliferation may be investigated by direct inoculation of soil particles onto agar media and observing after 24 hours. This method is unfortunately highly selective for fast-growing fungi and Warcup considers it very unreliable.

Mueller and Durrell (1957), Chesters (1940, 1948), and Chesters and Thornton (1956) are among those having used immersion tubes to isolate the actively-growing fungal hyphae from soil. Probably a few spores are also encouraged to germinate, but the method seems useful

for isolating many different species which might otherwise not be recognised.

Compared with bacterial enumeration, fairly low dilutions and more acid media are usually employed (Warcup 1960). Martin's (1950) Acid-Rose Bengal-Streptomycin medium has been used as the standard in several recent investigations (Paharia and Kommedahl 1954, Miller and Webb 1954, Butler and Hine 1958, Johnson and Manka 1961 etc.). Other common media include soil extract, with or without yeast extract (Sewell 1959, Johnson and Manka 1961), Czapek dox and yeast (Sewell 1959, Parkinson and Thomas 1965), and dextrose-peptone-yeast extract-oxgall (Johnson and Manka 1961), with varying success reported.

The use of Novobiocin at 100 µg/ml of medium with a potato-dextrose agar was initiated by Butler and Hine (1958), and they found it as good as Martin's Rose Bengal-Streptomycin in respect to both numbers and species, and superior in eliminating bacteria. In addition, fewer fungal colonies remained submerged on the pour plates and they could therefore be more readily subcultured and identified. Martin's medium, however, was more efficient in reducing colony size, thus allowing slower-growing species to develop. The standard Rose Bengal-Streptomycin medium and this Potato-dextrose-Novobiocin medium were used in the present study.

Enumeration

The ideal colony count per plate for dilution plates has been variously extimated by different workers. Too few colonies per plate tends to give an erroneous, (often high) count for the sample (Vitgeft 1963), whereas with a large number interference occurs. Warcup (1960)

quotes Waksman's figure of 30 - 100, Brierley (34 - 45) and Bisby et al. (about 25), as the ideal numbers. James and Sutherland (1940a) point out that an estimation from one dilution can be very misleading, and that a measurement based on counts from two different dilutions is better. They also suggest using a correction factor with the figures, but this has the disadvantage that a new graph has to be plotted for each set of results and the mechanics are therefore time-consuming and not justified for a general survey of the soil microflora.

Microflora of peat bogs

General considerations

The idea was formerly prevalent that peat is sterile below the surface, presumably due to its acidity (pHs of 3 to 5 are usual), anaerobiosis and poverty in inorganic nutrients. This conception has been revised in the last decades by the studies of Waksman (for example Waksman and Purves 1932) and many others. Although the peat microflora is probably less diverse than in mineral soils, (Stout 1961), the numbers may be just as high (Beck and Poschenrieder 1958, Rehm and Sommer 1962), and do not decrease steadily but increase again at depth, coinciding with the increased humification of the peat in the deeper horizons, (Küster 1963, Waksman and Purves 1932). Ivarson (1965) found that in Arctic peat, numbers generally decreased with depth, the decrease being of greater magnitude in the permafrost layers. However Katsnel'son and Ershov (1958) pointed out that it is the activity, not the numbers of micro-organisms that is significant. They concluded that peat soils possessed generally higher activities than mineral soils, and that the microflora in peats was active throughout the profile. Stout (1961) and

Pochon (1956) disagree, as they consider peat micro-organisms less active than those of mineral soils.

Bacteria

The bacteria are distinct in type, and distribution down the peat profile (Stout 1961). As would be expected in this extremely wet environment (85% to 95% water is common), the numbers of aerobic bacteria were found by Waksman and Stevens (1929) to decrease rapidly down the profile, whilst the anaerobes increased rapidly with depth. Figures for total bacteria of 30 thousand to 1.2 million per gram of OD soil (Waksman and Purves 1932), 0.9 - 23.4 million (Christensen and Whittingham 1965), 2 - 47 million (Zhukova 1956) and 6 - 27 million (Rehm and Sommer 1962) have been reported. Quotes for aerobic and anaerobic bacteria differ; Waksman and Purves (1932) found 18 - 890 thousand aerobes and 16 - 380 thousand anaerobes, the highest figures for both being at 165 cm depth. However Beck and Poschenrieder (1958) report 2.6 - 8.1 million aerobes and .3 to 8.3 million anaerobes, also both most abundant at the greatest depth (185 cm). Stout (1961) found that up to one third of his bacteria were spore-forming Bacilli, and that generally these were less common than in mineral soils; but Zhukova (1956) only found 1 - 8% were spore-formers.

Working with permafrost layers Boyd (1958) reported that Arctic peats contained 2 - 60 million bacteria per gram, similar to figures for temperate zones. Thermophiles, growing at 55°C, have been reported above and through permafrost layers by McBee and McBee (1956), and in a later study Boyd and Boyd (1964) found that these were mostly spore-formers. The counts for mesophiles (22°C) dropped from 94,000 above the permafrost to 76 in the frozen layer. Ivarson (1965) in his

work on Arctic peat discovered that the numbers of organisms growing at 25°, 10° and 4°C were relatively constant in the frozen, and in the unfrozen horizons.

Röschenthaler and Poschenrieder (1958) and Poschenrieder (1958) reported a sequence of genera through the profile. Micrococcus was especially abundant in the surface layers, Achromobacter in the middle of the profile, and Pseudomonas at about 250 cm, in both sphagnic and fen peats.

Actinomycetes

Generally, very small numbers of actinomycetes have been found in peat bogs, probably due to their inability to tolerate acidity. Christensen and Whittingham (1965) reported 100 - 400 thousand per gram, Waksman and Purves (1932) 3 - 370 thousand, 'almost none' were found by Pochon (1956), and none by Zhukova (1956). Numbers are highest at the surface and decrease sharply with depth (Waksman and Stevens 1929), but even at the surface actinomycetes do not play a great role, at least numerically (Rehm and Sommer 1962).

Fungi

Fungi have, notably, only been reported from surface horizons of acid peat (Waksman and Stevens 1929, Waksman and Purves 1932, Stout 1961, and Boyd and Boyd 1964), and also in only the surface horizons of alkaline peat (pH 6.5 to 8.0) by Stenton (1953). Poschenrieder and Beck (1958) found 1 - 55 thousand per gram, Rehm and Sommer (1962) 1.5 - 3 thousand, and Christensen and Whittingham (1965) reported 12.2 thousand to 6 million in their detailed investigations. Dahman and Ramant (1954), Küster (1963) and Christensen and Whittingham (1965) all report a

dominance of Penicillia, and other common genera seem to be Yeasts (Christensen and Whittingham 1965) and Cladosporium, Aleurisma and Cephalosporium (Dahman and Ramant 1954, Küster 1963). The proliferation of the latter three is suggested to be due to their strong cellulolytic activity. Christensen and Whittingham (1965), who identified 78 species, noted that approximately half of these appeared to be rare or absent in mineral soils. They also found that they could correlate the species composition in the microfungal communities with the species composition and maturity of the overlying higher plant community.

Algae

Chapman (1962) considers that bogs and swamps have very mixed associations of algae, with little or no seasonal periodicity, probably because of the relatively uniform conditions. Zygnemaceae, desmids and diatoms are the most frequently demonstrated algae of peatlands.

Physiological considerations

Most workers have noted the generally low activity of micro-organisms in peat. Waksman and Purves (1932) reported that Sphagnum remains are rich in cellulose and hemicelluloses highly resistant to decomposition. Waksman and Stevens (1929) found aerobic cellulose-decomposing bacteria in surface horizons only, and Pochon (1956) concluded that the much-reduced cellulolytic activity was due to the great acidity and high organic matter content in relation to the wide C/N ratio of peat.

Pochon also reports almost no micro-organisms carrying out transformations of nitrogen. Denitrification has been shown to proceed very slowly, both aerobically and anaerobically (Barjac 1954), and

Pochon and Naghib (1956) report more aerobic denitrifiers than anaerobic. Non-spore-formers predominate at the surface, and spore-formers in the deeper horizons (Pochon and Naghib 1956). This might suggest that little denitrification is actually proceeding at depth, but that the bacteria capable of doing so are present in a dormant state. Nitrifying bacteria were found only at the surface by Waksman and Stevens (1929). Zimenko (1957), and Zhukova (1956) report rapid mineralisation especially by spore-formers, and this ties in with the observations of Christensen and Whittingham (1965) that more ammonium than nitrate nitrogen was present in their peat samples, as it is well known that nitrification is extremely slow in acidic conditions. Zhukova (1956) seems to be the only person reporting denitrification and nitrogen-fixation in any quantity in peat, compared to mineral soils.

Microbial activity of soil is often measured by means of carbon dioxide evolution or by catalytic activity, for example of catalase, saccharase or protease. Katsnel'son and Ershov (1958) concluded that saccharase and protease determinations gave the most valid characteristics of soil activity.

Special groups

Myxobacteria have been reported from soils of the Alaskan and Canadian Arctic by Brockman and Boyd (1963), and Stout (1961) noted a high proportion of Chromobacterium species in a highly decomposed type of peat with which he worked.

MATERIALS AND METHODS

A. MATERIALS

1. Sampling sites for detailed study

Three peat bogs were sampled, using three profiles each one foot apart, and henceforth known as A, B and C, in each of the three peat pits. Physical, chemical and vegetation analyses were made for each site, with detailed microbiological characterisation of the separate profiles.

Two of the three sampled areas occurred in central Alberta, both about 70 miles west of Edmonton. The other was located about 250 miles north-west of these sites, about 15 miles west of the town of Peace River, and very close to the 6th Meridian. Their geographical positions are indicated on the accompanying map, (Fig. 1, page 23, site numbers 8, 10 and 15).

(i) Granada Humisol

This site is situated in an area having approximately 57 cm. annual precipitation, 38 cm. of this falling during the May to September period and 19 cm. during October to April. The mean annual temperature is 2.5^{o}C and the mean annual frost-free period is about 60 to 75 days.

(ii) Evansburg Mesisol

This site experiences an annual precipitation of approximately 53 cm. with 34 cm. of this being received during the summer and 19 cm. during the winter months. The mean annual temperature is approximately 2.5^{o}C and there are roughly 75 to 90 frost-free days each year.

Peat Sites

1. Beaverlodge
2. Bellis
3. Brainard
4. Debolt
5. Dixonville
6. Drayton Valley
7. Eaglesham
8. Evansburg *
9. Glenister
10. Granada *
11. Grassland
12. Greencourt
13. Gunn
14. Magnolia
15. Meridian *
16. Peers
17. Wanham
18. Wembley
19. Whitecourt
20. Winterburn

* Used for detailed microbiological study.

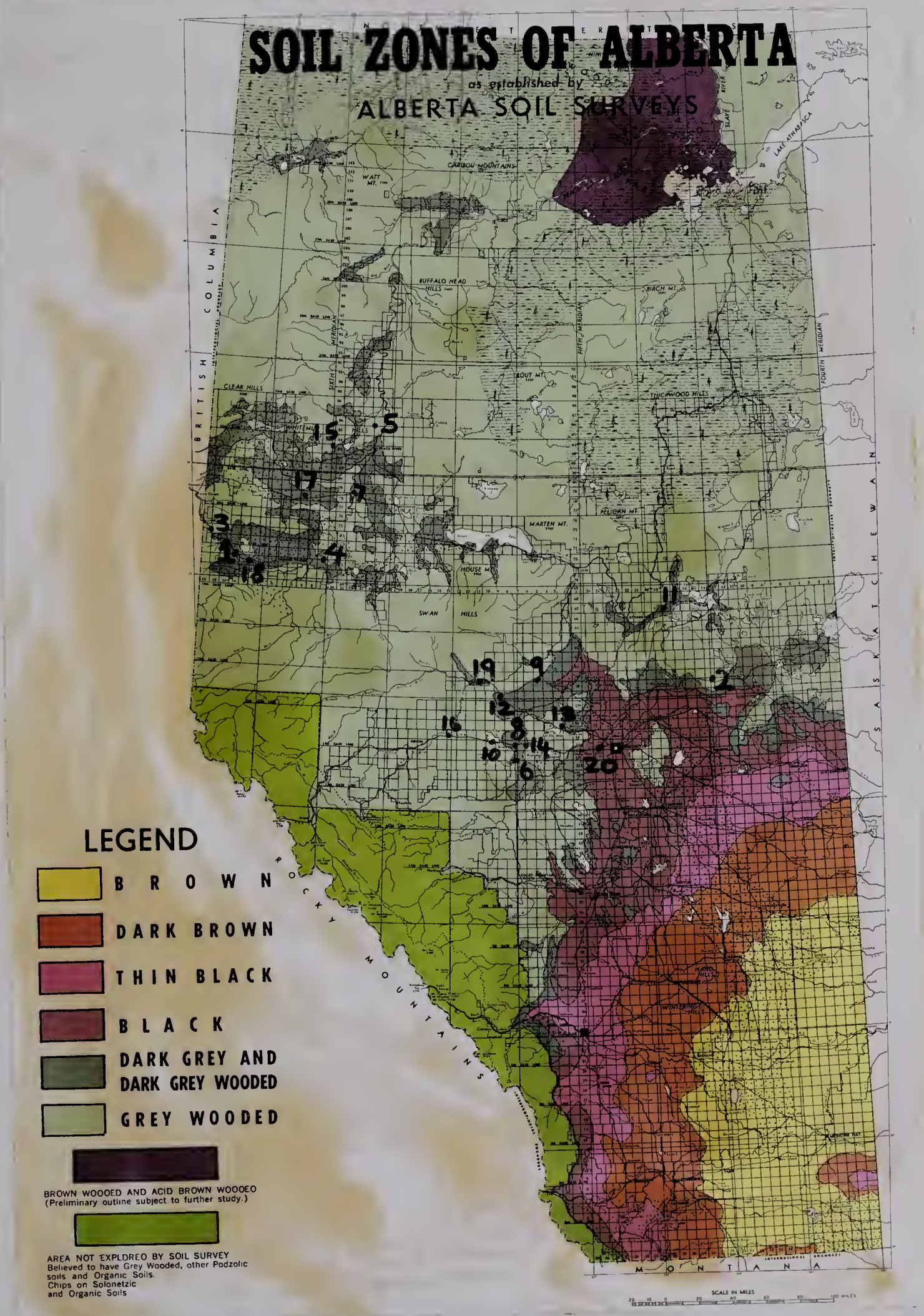


Figure 1. Locations of the Sites of Peat Sampling.

(See facing page)

Table 1. Profile description. Site 1. Beaverlodge. Terric straticmeso-Fibrisol

Location: SE 5 72-8-6. 2.0 miles north of highway on La Glace road and 1.0 miles west on Beaverlodge road. North side of road, 40 yards back.

Vegetation:

Trees:	Picea mariana	D*
Herbs:	Ledum groenlandicum	D
	Ribes sp	A
	Vaccinium vitis-idaea	C
	Oxycoccus microcarpus	F
Mosses:	Sphagnum megallanicum	CoD*
	S. warnstorfianum	CoD
	Pleurozium schreberi	CoD
	Dicranum scoparium	LF
	Ptilium crista-castrensis	LF
Lichens:	Parmelia saxatilis	F
	Usnea spp.	C
	Cladonia impexa	O
	Cladonia spp.	O
	Peltigera aphthosa	O

Horizon	Depth	Munsell colour(moist)	Fibres	Composition	Van Post Test**
L	0-6"	10YR 7/4 and 10YR 5/3	Coarse 100%	Live and slightly decomposed Sphagnum, many roots	Clear
L	6-12"	10YR 6/6 with	Medium 90%	Sphagnic, non-greasy, many roots	Cloudy
		10YR 5/3	Medium 80%	Mucinic, slightly greasy, many roots	Cloudy
L	12-21"	10YR 6/6 with pockets of 10YR 5/3	Medium 80%	Sphagnic, non-greasy, matted, no roots	Very cloudy
			Medium to fine 60%	Mucinic and fennic, greasy	Very cloudy
F/H	21-31"	10YR 3/3	Mainly fine 30%	Probably mucinic, very greasy, some mineral	Muddy
Ah	31-37"	10YR 2/2	Fine and medium 10%	Some fennic, high mineral content	-
-	37-40"	10YR 3/1	-	Mineral substratum, clay-loam, some humic organic matter	-

Special characteristics: Water accumulated at 30". Medium density Spruce cover, average 20 feet in height. Dense cover of Ledum.

*See text (page 51) for key to symbols.
**See text (page 54) for description of text.

Table 2. Profile description. Site 2. Bellis. Terric mesic Fibrisol

Location: SW 27 60-14-4. 6.0 miles north of intersection of highways 28 and 36 (near Bellis). East side of road, 20 yds. north and east of section corner.

Vegetation:			
Trees:	Picea mariana	D	
Herbs:	Ledum groenlandicum	D	
	Vaccinium vitis-idaea	C	
	Oxycoccus microcarpus	F	
	Ribes sp	O	
	Maianthemum canadense	LF	
Macro-fungi:	Brown toadstools	O	
Mosses:	Sphagnum warnstorfianum	LA	
	Ptilium crista-castrensis	C	
	Tomenthypnum nitens	C	
	Dicranum scoparium	O	
	Aulacomnium palustre	O	
	Polytrichum juniperinum	O	
Lichens:	Cladonia impexa	LF	
	Cladonia spp.	LA	
	Parmelia saxatilis	F	

Horizon	Depth	Munsell colour(moist)	Fibres	Composition	Van Post Test
L	0-6"	5YR 4/6 and 5YR 3/4	Medium to coarse 95%	Loose, slightly decomposed Sphagnum, non-greasy.	Clear
L	6-12"	5YR 2/2 and 5YR 4/6	Coarse to medium 70-80%	Mucinic, greasy, fairly loose.	Cloudy
		2.5 YR 4.8	10%	Woody inclusions.	
L	12-18"	5YR 3/4	Medium 80%	Mucinic, non-greasy. Inclusions of mesic mucinic material and a 1/4" layer of charcoal.	Very cloudy
L/F	18-24"	5YR dominant and 10YR 2/1	Medium 70% and Fine 20%	Matted mucinic, with small pockets of humic material.	Very cloudy
L/F	24-28"	5YR 3/3 dominant and 10YR 2/1	Medium 70% and Fine 20%	Matted mucinic, with small pockets of humic material, and 5% woody material	Very cloudy
H	28-33"	5YR 3/3 and 5YR 2/1	Coarse to fine 20%	Fennic, greasy, humic, woody (5%), some mineral present.	Muddy
-	at 33"	2.5YR 5/2	-	Mineral substratum, clay.	

Special characteristics: Water accumulated at 24". The area was burnt over, with Black Spruce regeneration to about eight feet. Area just south was not burned and indicates original vegetation (Spruce-Sphagnum) but was too wet for effective sampling.

Table 3. Profile description. Site 3. Brainard. Mesic Fibrisol

Location: SE 14 74-12-6. 0.7 miles west of junction of highway and Sexsmith road, on north side of highway, 40 yds. back.

Vegetation:			
Trees:	Picea mariana	D	
Herbs:	Ledum groenlandicum	D	
	Vaccinium vitis-idaea	A	
	Oxycoccus microcarpus	F	
Mosses:	Polytrichum juniperinum var. gracile	FLA	
	Dicranum undulatum	FLA	
	Ceratodon purpureus	FLA	
	Aulacomnium palustre	FLA	
	Tomenthypnum nitens	FLA	
	Sphagnum warnstorfianum	FLA	
Lichens:	Cladonia spp	LC	
	C. impexa	O	
	Parmelia saxatilis	F	
	Usnea spp.	O	

Horizon	Depth	Munsell colour(moist)	Fibres	Composition	Van Post Test
L	0-8"	10YR 5/4	Medium 90%	Live and slightly decomposed mosses, mostly sphagnic, loose	Clear
L	8-14"	10YR 3/4	Coarse 90%	Loose, partially decomposed, mucinic, non-greasy	Slightly cloudy
L	14-18"	10YR dominant 10YR 2/1	Medium 80%	Mucinic, non-greasy, includes 1/2" layer with much charcoal	Cloudy
L	18-28"	10YR 5/8	Medium 80%	Mucinic, non-greasy, matted	Almost clear
-	28-29"	10YR 2/1	-	Woody and charcoal layer	-
L/F	29-39"	10YR 5/8	Medium to fine 70%	Mucinic, slightly greasy, matted	Cloudy
F	39-53"	10YR 5/6 10YR 3/3	Coarse to fine 60% Medium 60%	Mucinic with some fennic, matted, small pockets containing some wood	Very cloudy
F	53-61"	10YR 4/4	Coarse to medium 50%	Mucinic, slightly greasy, some fennic remains	Muddy
-	At 70"	-	-	Mineral substratum	-

Special characteristics: Water collected at four feet. Dense Spruce cover, mainly 10-12 feet high, many smaller trees. Dense cover of Ledum.

Table 4. Profile description. Site 4. Debolt. Stratic mesic Fibrisol

Location: SW 7 72-26-5. On highway 0.2 miles east of crossroads at Debolt school. North side of road, 100 yds. north of highway.

Vegetation:

Trees:	Picea mariana	D
Herbs:	Ledum groenlandicum	D
	Vaccinium vitis-idaea	A
	Oxycoccus microcarpus	C
	Maianthemum canadense	C
	Ribes sp	F
Macro-fungi:	Brown and white toadstools	F

Mosses:	Sphagnum warnstorfianum	D
	Polytrichum juniperinum var gracilius	C
	Tomenthypnum nitens	C
	Dicranum scoparium	C
	Ceratodon purpureus	C
Lichens:	Cladonia impexa	LF
	Cladonia spp.	O
	Parmelia saxatilis	O
	Peltigera aphthosa	O

Horizon	Depth	Munsell colour(moist)	Fibres	Composition	Van Post Test
L	0-3"	Variable	-	Live sphagnum etc., very variable	Dry
L	3-9"	5YR 4/6	Medium 80%	Stratified, sphagnic, many roots, pockets of mesic material	Cloudy
L(F)	9-16"	Mainly 5YR 4/6 5YR 2/2	Medium 80% Fine 50%	Stratified, sphagnic, with roots Smaller bands of mesic, greasy material	Cloudy Very cloudy
L(F)	16-24"	5YR 4/4 5YR 3/3	Medium 80% Fine 50%	Stratified, sphagnic, with roots Smaller bands of mesic, greasy material	Cloudy Very cloudy
L/F	24-33"	5YR 4/6 and 5YR 3/3	Medium 70%	Stratified, mucinic, non-greasy. Thin bands of charcoal (1/4")	Cloudy
L/F	33-41"	5YR 4/4 and 5YR 3/2	Medium 70%	Stratified, mainly mucinic, non-greasy, matted, some wood. Thin charcoal band	Very cloudy
F	41-47"	5YR 3/4	Coarse to medium 60%	Matted, mainly mucinic, slightly greasy, 5% wood	Very cloudy
F	47-51"	5YR 3/3	Fine 40%	Mucinic, greasy	Muddy
F	51-61"	5YR 3/2	Medium to fine 50%	Mucinic, greasy, some wood	Muddy
	About 10'	-	-	Mineral soil	-

Special characteristics: Water collected at 36". Spruce mainly five to six feet high, few over ten feet. Light open cover, generally dry.

Table 5. Profile description. Site 5. Dixonville. Stratic mesic Fibrisol

Location: SW 29 88-23-5. 8.2 miles north of Dixonville on highway. East side of road, 30 yds. back.

Vegetation:						
Trees:	Picea mariana	D	Mosses:	Polytrichum juniperinum	F
Herbs:	Ledum groenlandicum	D		Dicranum undulatum	F
	Vaccinium vitis-idaea	C		D. scoparium	F
	Oxycoccus microcarpus	F		Ceratodon purpureus	F
	Ribes sp	F		Pleurozium schreberi	F
	Maianthemum canadense	O	Lichens:	Peltigera aphthosa	F
				Cladonia spp (not impexa)	F
				Parmelia saxatilis	R

Horizon	Depth	Munsell colour(moist)	Fibres	Composition	Van Post Test
L	0-5"	5YR 4/6	Medium to fine 70%	Mucinic, non-greasy, many roots	Cloudy
L(F)	5-13"	5YR 5/6	Medium 80%	Mucinic, non-greasy, matted, highly stratified	Slightly cloudy
		5YR 3/2	Medium to fine 60%	Layers with some charcoal	Cloudy
F(L)	13-18"	5YR 3/3	Fine 50%	Mucinic, greasy, some charcoal	Cloudy
		and 5YR 4/6	Medium 70%	Mucinic, non-greasy	Cloudy
L/F	18-30"	5YR 3/4	Medium 70%	Mucinic, non-greasy, matted	Cloudy
		and 5YR 2/2	Fine 50%	Greasy, some charcoal	Cloudy
L/F	30-42"	10YR 5/6	Medium 70%	Mucinic, non-greasy, some thread-like fibres	Cloudy
		and 10YR 3/2	Medium to fine 50%	Mucinic, slightly greasy	Cloudy
F	42-54"	10YR 4/2	Medium 60%	Mucinic, non-greasy, many thread-like fibres, some wood. Stratified, but little colour variation	Cloudy
F	54-60"	10YR 3/2	Medium and fine 60%	Fennic and mucinic, greasy, woody, pockets of	Muddy
	>68"	10YR 5/6	Medium 70%	Mucinic	
		-	-	Mineral soil	

Special characteristics: Water collected at 36". Black Spruce formerly dominant, but recently burnt over, thus now has dry open cover. Regeneration up to one foot only. Dense cover of Ledum. In 1964 ice occurred between 36 and 40". 1965 no ice was detected, although it was cold at depth (3°C). However, under denser cover, a permanent ice layer could be expected.

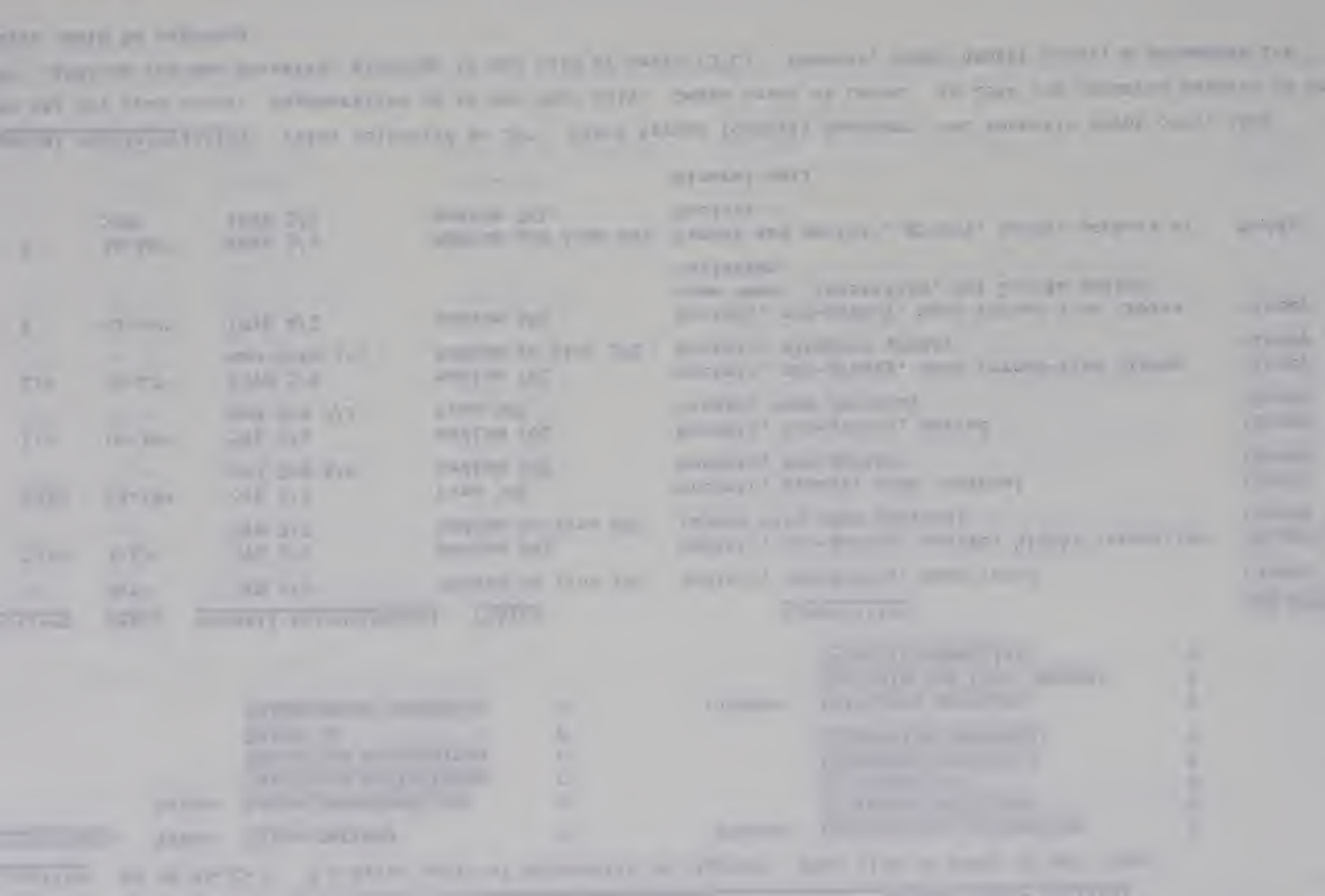


Table 6. Profile description. Site 6. Drayton Valley. Terric fibric Humisol

Location: NW 9 50-5-5. 6 miles north of Drayton Valley, and 100 yds. east on south side of road. Sampled in road ditch.

Vegetation:			
Trees:	Picea glauca	D	
	Salix spp	A	
Herbs:	Epilobium angustifolium	A	
	Vaccinium vitis-idaea	C	
	Solidago sp	C	
	Equisetum sp	F	
	Ledum groenlandicum	F	
	Grasses and sedges	O	
Mosses:	Tomenthypnum nitens	F	
	Ceratodon purpureus	F	
	Ptilium crista-castrensis	F	
	Aulacomnium palustre	F	
Lichens:	Peltigera aphthosa	O	
	Cladonia spp	O	

Horizon	Depth	Munsell colour(moist)	Fibres	Composition	Van Post Test
L	0-4"	Mainly 10YR 5/4	Coarse 100%	Loose undecomposed and slightly decomposed feather mosses	-
L/F	4-8"	10YR 3/4 and 10YR 5/6	Medium to fine 70%	Heterogeneous, mainly mucinic, with 5% wood and roots, non-greasy	Cloudy
H	8-14"	10YR 2/1 and some 10YR 3/3	Fine 30-40%	Mainly humic, 10% wood	Muddy
H	14-20"	10YR 2/1	Medium to fine 40-50%	Fennic, greasy, mainly humic, some wood	Muddy
-	20-23"	10YR 3/1 5 YR 4/6	-	Clay containing humic material and pockets of disintegrated wood	-
-	23-27"	10YR 5/1	-	Mineral substratum, lacustrine clay. Some mottling	-

Special characteristics: No water accumulated in pit. Incomplete recent burn. Site is on northern extremity of bog, and has good accessibility. Selected as example of Terric Humisol.

Table 7. Profile description. Site 7. Eaglesham. Terric Humisol*

Location: SW 18 78-25-5. 2.3 miles north of highway, 40 yds. in on east side of road.

Vegetation: Herbs: Carex sp D

Horizon	Depth	Munsell colour(moist)	Fibres	Composition	Van Post Test
F/H	0-4"	10YR 2/2	Fine 30-40%	Fennic, many roots, some clay	Muddy
F/H	4-11"	10YR 3/2	Medium and fine 40%	Fennic, some roots, some clay	Muddy
Ah	11-19"	10YR 3/1	-	Essentially clay with roots, and inclusions of mesic and humic organic material	-
Ah?	19-24"	10YR 5/1 with 10YR 5/8 mottling	-	Mineral with some organic matter	-

Special characteristics: Other digs at 280 yds. further into the bog, and in a separate bog one mile south revealed about 12" peat over mineral substratum.

*Classification uncertain, scarcely in organic order.

Table 8. Profile description. Site 8. Evansburg. Stratic fibric Mesisol

Location: On commercial property of "Mountain Meadow" peat Moss group (Banff Mining and Quarrying Ltd.). Near Evansburg, approximately one mile north of railway crossing on east side of bog. Sampled in three-month old drainage ditch.

Vegetation:

Trees:	Picea mariana	D	
	Betula spp	F	
Herbs:	Ledum groenlandicum	D	
	Oxycoccus microcarpus	C	
	Eriophorum gracile	C	
	Scirpus hudsonianus	F	
	Vaccinium vitis-idaea	F	
Mosses:	Sphagnum warnstorfianum	D	
	Drepanocladus aduncus	A	
	Polytrichum juniperinum	F	
	Other feathermosses	O	
Lichens:	Parmelia saxatilis	C	
	Parmelia spp.	C	
	Usnea comosa	C	
	Cladonia impexa	LA	
	C. fimbriata	C	
	C. coniocraea	C	
	Peltigera aphthosa	O	

Horizon	Depth	Munsell colour(moist)	Fibres	Composition	Van Post Test
L	0-7"	10YR 5/6	Medium 95%	Loose Sphagnum	Clear
F	7-11"	5YR 3/4 and 5YR 2/2	Fine, some medium 60%	Mainly mucinic, mesic, greasy, some roots and small woody fragments	Cloudy
L/F	11-19"	5YR 4/4	Coarse to fine 80%	Fennic, some mucinic, partly decomposed, matted, mesic-fibric	Cloudy
F	19-25"	5YR 3/4	Coarse and fine 60%	Fennic and mucinic, mesic, stratified, greasy, some well-decomposed inclusions (10YR 2/1)	Very cloudy
F	25-31"	5YR 3/4	Coarse and fine 60%	Fennic and mucinic, mesic, stratified, greasy, some well-decomposed inclusions (10YR 2/1)	Very cloudy
F	31-36"	10YR 3/1	Coarse and fine 50%	Fennic, greasy, some wood	Cloudy
F	36-42"	10YR 3/1	Coarse and fine 50%	Fennic, greasy, some wood	Cloudy
F	42-52"	5YR 3/1 with 5YR 4/3	Medium to fine 40% Coarse 60%	Fennic, greasy, some wood and charcoal Fennic, compact, greasy, 10% wood	Cloudy Cloudy

Special characteristics: Water below 40" in July. Flora examined 10 yds. back into forest. Medium cover of Spruce, light Ledum cover.

Plate 1. Evansburg Bog Location of Site

Profile

Horizons

I L
II F
III LF
IV F
V F
VI F
VII F
VIII F

Table 9. Profile description. Site 9. Glenister. Stratic fibric Mesisol

Location: SW 19 58-6-5. 1.0 mile south and 2.0 miles west of Glenister, on Sangudo-Barrhead road. 50 yds. north and east of section corner.

Vegetation:

Trees:	Picea mariana	D	
Herbs:	Ledum groenlandicum	D	
	Vaccinium vitis-idaea	A	
	Oxycoccus microcarpus	A	
Mosses:	Sphagnum warnstorfianum	C	
	S. megallanicum	F	
	Polytrichum juniperinum	F	
	Pleurozium schreberi	F	
	Dicranum undulatum	F	
	D. polysetum	O	
	Aulacomnium palustre	F	
	Tomenthypnum nitens	O	
	Ceratodon purpureus	O	
Lichens:	Cladonia impexa	F	
	Cladonia spp.	F	
	Parmelia saxatilis	F	

Horizon	Depth	Munsell colour(moist)	Fibres	Composition	Van Post Test
L	0-3"	-		Mixed surface vegetation, undecomposed and partly decomposed	-
L	3-10"	10YR 5/8	Medium 90%	Mucinic	Almost clear
L/F	10-20"	10YR 5/6 10YR 2/1	Medium 80% Fine 50%	Mucinic, with minor 1/2" layers and containing charcoal	Cloudy Cloudy
F	20-30"	10YR 3/3 10YR 2/1	Medium 60% Fine 50%	Mainly fennic, slightly greasy, matted, also 1/2" layers of decomposed material	Very cloudy Muddy
L/F	30-34"	5YR 4/6	Coarse to medium 80%	Mucinic and fennic, non-greasy, some wood	Cloudy
F	34-52"	5YR 4/6 and 5YR 3/4	Medium to fine 70%	Mixed mucinic and fennic, slightly greasy, 5% wood	Cloudy
F	Below 60"	5YR 2/2	Medium to fine 50%	Mainly fennic, greasy, 5% wood, some shells	Muddy

Special characteristics: Medium dense Spruce cover, 10-20 feet high. Very little surface water.

Table 10. Profile description. Site 10. Granada. Terric stratic mesic Humisol

Location: One mile east of Granada, 100 yds. south of highway. Sampled in new road cut (this year) on east side of road.

Vegetation:					
Trees:	Picea mariana	D	Mosses:	Tomenthypnum nitens	CoD
	Salix spp	F		Dicranum scoparium	A
	Larix laricina	O		Aulacomnium palustre	CoD
Herbs:	Ledum groenlandicum	D		Polytrichum juniperinum	A
	Vaccinium vitis-idaea	F		Sphagnum warnstorfianum	O
	Oxycoccus microcarpus	F	Lichens:	Cladonia impexa	LF
	Grasses	F		Cladonia spp.	LF
	Equisetum sp	O		Parmelia saxatilis	F
	Parnassia montanensis	O		Peltigera aphthosa	F

Horizon	Depth	Munsell colour(moist)	Fibres	Composition	Van Post Test
L	0-6"	10YR 5/6	Coarse 90%	Loose feathermosses, this sample taken 10 yds. back from road cut	Cloudy
F/H	6-10"	10YR 5/8 and 10YR 2/1	Medium 60% Medium to fine	Heterogeneous with darker material predominating, mainly fennic	Muddy
L/F	10-13"	10YR 3/4 and 10YR 3/1	Medium and fine 70%	Mainly fennic, some mucinic, charcoal present	Clear
H	13-28"	10YR 2/1 and 10YR 4/4	Fine 30% Medium 60%	Mucinic and fennic, stratified, well-decomposed, 5% wood, some lighter coloured mesic inclusions	Muddy
H	28-40"	10YR 2/1 and 3/1	Fine 10%	Fennic, humic, 10% wood, some mineral matter	Very cloudy
-	At 40"	-	-	Clay loam to clay substratum	-

Special characteristics: Water table below 40". Fairly dense Spruce cover, medium Ledum cover.

Plate 2. Granada Bog Location of Site

Profile

Horizons

I L

II F/H

III 4/F

IV H

V H

Table 11. Profile description. Site 11. Grassland. Stratic fibro-humic Mesisol

Location: SW 3 67-18-4. 0.8 miles east of Sarrail and 4.0 miles south of Grassland. Samples near centre of bog that crosses road. Pit located 40 yds. north of road.

Vegetation:						
	Trees:	Picea mariana	D	Mosses:	Sphagnum warnstorfianum	CoD
		Salix spp	C		S. megallanicum	CoD
		Larix laricina	F		S. recurvum	CoD
	Herbs:	Ledum groenlandicum	D		Pleurozium schreberi	LF
		Vaccinium vitis-idaea	A		Aulacomnium palustre	LF
		Ribes sp	A		Polytrichum juniperinum	F
		Oxycoccus microcarpus	C		Jamesoniella autumnalis	F
		Empetrum nigrum	LF	Lichens:	Parmelia saxatilis	F
		Eriophorum gracile	O		Cladonia impexa	O
		Drosera rotundifolia	R		Cladonia spp.	O

Horizon	Depth	Munsell colour(moist)	Fibres	Composition	Van Post Test
L	0-8"	7.5YR 6/8		Loose undecomposed Sphagnum	
L	8-16"	5YR 2/6	Coarse 95%	Slightly decomposed Sphagnum	Almost clear
L	16-20"	5YR 4/6	Coarse to medium 80-90%	Mucinic, matted, many roots	Almost clear
F	20-28"	5YR 3/4	Medium to fine 70%	Mainly mucinic, matted, non-greasy,	Cloudy
		and 5YR 2/1	Medium to fine 50%	stratified, mucinic, matted, non-greasy	Cloudy
F	28-34"	5YR 4/6	Coarse to medium 70%	Stratified, non-greasy, mucinic	Cloudy
		10YR 2/1	Medium to fine 30%	Humic, fennic, charcoal present, and some wood	Muddy
F	34-46"	10YR 2/1	Medium to fine 30%	Stratified material similar to the above	

Special characteristics: Water collected at 60". Peat probe would be needed to reach mineral substratum.

Table 12. Profile description. Site 12. Greencourt. (Stratic) fibric Mesisol

Location: NE 20 58-9-5. 2.8 miles NW on highway from Greencourt crossroads, 65 yds. north on cut line, 8 yds. west.

Vegetation:						
Trees:	Picea mariana	D	Mosses:	Polytrichum juniperinum var. gracilius	A
	Betula sp	O		Aulacomnium palustre	A
Herbs:	Ledum groenlandicum	D		Tomenthypnum nitens	A
	Vaccinium vitis-idaea	A		Ptilium crista-castrensis	A
	Oxycoccus microcarpus	F		Sphagnum warnstorfianum	F
	Carex spp	C		Ceratodon purpureus	F
Macro-fungi:	Toadstools	O	Lichens:	Parmelia saxatilis	F
				Cladonia spp	F

Horizon	Depth	Munsell colour(moist)	Fibres	Composition	Van Post Test
L	0-8"	5YR 5/6	Coarse and medium 90%	Loose, slightly decomposed feather-mosses, with many roots	
L	8-16"	5YR 4/6	Coarse to medium 70-80%	Mucinic and fennic, non-greasy	Cloudy
L/F	16-24"	5YR 4/8 with pockets of 5YR 2/2	Coarse to medium 70%	Mainly fennic, matted, slightly greasy, some wood	Cloudy
F	24-32"	5YR 4/3	Medium to fine 60%	Fennic, greasy, matted, some wood	Very cloudy
F	32-42"	5YR 3/3	Medium to fine 70%	Mucinic and fennic, non-greasy, some wood	Cloudy
F	42-50"	5YR 3/4	Medium to fine 60-70%	Fennic and mucinic, slightly greasy, 5% wood	Very cloudy
		5YR 5/6	Medium	Pockets mainly mucinic	

Special characteristics: Black Spruce cover fairly dense with stand of 10-20 feet in height. This is known to be a deep bog, but sampling below 50" was prevented by excess water.

Table 13. Profile description. Site 13. Gunn. Terric Mesisol

Location: SW 14 55-3-5. 1.1 miles north of highway at Gunn, east side of road in depression.

Vegetation:					
Herbs:	Carex sp	D	Mosses:	Drepanocladus aduncus	C
	Scutellaria galericulata	O			
	Mentha arvensis	O			
	Rumex occidentalis	O			
	Aster puniceus	O			

Horizon	Depth	Munsell colour(moist)	Fibres	Composition	Van Post Test
F	0-5"	10YR 3/2	Coarse and medium 60%	Fennic, partially decomposed, greasy, many roots	Muddy
F	5-11"	10YR 2/2 10YR 4/4	Medium and fine 60%	Fennic, woody, some roots, pockets of woody material	Muddy
F	11-17"	10YR 3/1	Coarse to fine 60%	Fennic, matted, slightly greasy, some wood	Muddy
F	17-23"	10YR 3/2	Coarse to fine 60%	Fennic, greasy, matted, smelly, some wood	Muddy
-	At 23"	10YR 4/1	-	Mineral substratum, clay with inclusions of small shells and some wood	

Special characteristics: A small sedge bog with dense cover of sedge to a uniform height of three feet.

Table 14. Profile description. Site 14. Magnolia. Stratic mesic Fibrisol

Location: 4.0 miles north of Magnolia bridge, east side of road, in the ditch.

Vegetation:						
Trees:	Picea glauca	D	Mosses:	Sphagnum warnstorfianum	CoD
				Feathermosses	CoD
Herbs:	Ledum groenlandicum	C		Polytrichum juniperinum	O
	Vaccinium vitis-idaea	C			
	Eriophorum gracile	F	Lichens:	Parmelia saxatilis	F
				Usnea comosa	F
				Cladonia spp	F

Horizon	Depth	Munsell colour(moist)	Fibres	Composition	Van Post Test
L	0-12"	Dom. 10YR 5/8	-	Loose Sphagnum, feathermosses, etc.	
L	12-19"	10YR 5/6 and 10YR 4/3	Medium 80%	Mixed strata, mucinic, slightly matted, non-greasy	Cloudy
L	19-24"	10YR 6/4 10YR 2/1	Medium 70-80%	Mucinic with some fennic, some 1/2" layers of humic material	Cloudy Muddy
L/F	24-28"	Mainly 10YR 4/3	Medium and fine 70%	Mucinic and fennic, slightly greasy, partly decomposed	Cloudy
L/F	28-35"	10YR 5/8 with 4 thin bands of 10YR 3/3	Coarse to fine 70%	Fennic and mucinic, slightly greasy, humic bands	Cloudy Muddy
L/F	35-42"	10YR 5/6	Coarse to fine 60%	Mainly fennic, non-greasy, some wood	Cloudy
F	42-50"	10YR 4/4	Coarse to fine 60%	Fennic, greasy, matted, some wood	Cloudy
F	50-58"	10YR 4/3	Coarse to fine 50-60%	Fennic, greasy, some wood	Very cloudy

Special characteristics: Site was in clear area of bog. 100 yds. south of site, no mineral substratum down to 92".

Table 15. Profile description. Site 15. 6th Meridian. Cryic stratic mesic Fibrisol

Location: NE 24 83-1-6. 0.4 miles west of meridian on Grimshaw-Hines Creek road. South side of road, 20 yds. back.

Vegetation:

Trees:	Picea mariana	D
Herbs:	Ledum groenlandicum	D
	Vaccinium vitis-idaea	F
	Ribes sp	F
	Oxycoccus microcarpus	O
Mosses:	Sphagnum warnstorfianum	LF
	S. recurvum	LF
	Dicranum scoparium	O
	D. undulatum	O
	Jamesoniella autumnalis	O
Lichens:	Cladonia impexa	LA
	Cladonia spp.	A
	Parmelia saxafilis	F
	Usnea spp.	F

Horizon	Depth	Munsell colour(moist)	Fibres	Composition	Van Post Test
L	0-6"	10YR 5/6	-	Live and slightly decomposed mosses	Clear
F	6-12"	5YR 4/6 and 5YR 3/3 10YR 5/8	Threadlike medium 50% 80%	Matted, some charcoal, many roots, woody Pockets of sphagnic material	Cloudy
L	12-17"	Mainly 5YR 4/8 5YR 3/2	Medium 80% Fine 40%	Mucinic, non-greasy. Smaller bands of with some charcoal	Cloudy Muddy
L(F)	17-20"	10YR 4/6 and 10YR 3/2	Mainly medium 80%	Mucinic, matted, frozen, stratified	Cloudy
L/F	20-32"	5YR 4/4 5YR 3/2	Medium 80% Medium to fine 50%	Mucinic, matted, non-greasy, and greasy, some charcoal	Very cloudy Muddy
L/F	32-38"	10YR 5/8 10YR 2/2	Medium to fine 70% Medium to fine 40%	Mucinic, slightly greasy, pockets of greasy material	Cloudy Muddy
F	38-47"	10YR 4/3	Medium to fine 60%	Fennic, slightly greasy, 5% wood	Muddy
F	47-55"	10YR 3/3	Medium to fine 40%	Fennic, greasy	Muddy

Special characteristics: Good stand of Spruce, large and small, some to 40 feet. Below frozen layer temperature remained +1.0°C down to four feet. 1964 dig indicated mineral layer at 48".

Temperatures recorded:

Air	9.0°C	6"	4.0°C	18"	0°C (in frozen layer)
1"	7.4°C	12"	1.6°C	26"	1.0°C
3"	6.6°C	17"	0.4°C	34"	1.0°C

Plate 3. Meridian Bog Location of Site

Table 16. Profile description. Site 16. Peers. Stratic humic Mesisol

Location: 0.5 miles north of last corner in Peers. East side of road in one-year-old road cut.

Vegetation:

Trees:	Larix laricina	D
	Betula spp	F
	Salix spp	F
	Picea glauca	O
Herbs:	Ledum groenlandicum	O
	Potentilla palustris	O
	Caltha palustris	O
	Menyanthes trifoliata	O
	Galium boreale	O
	Rubus acaulis	O
	Eriophorum gracile	O
Mosses:	Feathermosses	D
Lichens:	Peltigera aphthosa	O
	Usnea comosa	O
	Parmelia trichotera	O

Horizon	Depth	Munsell colour(moist)	Fibres	Composition	Van Post Test
L	0-2"	-	-	Loose feathermosses and sedges	
H	2-7"	10YR 3/2	Fine 30%	Fennic, fine granular, some well-decomposed wood, many roots	Muddy
H	7-12"	10YR 2/2	Fine 30-40%	Fennic, fine granular, well-decomposed some wood	Muddy
F	12-17"	10YR 4/3	Fine 50%	Fennic, mesic, matted, slightly greasy	Very cloudy
F	17-25"	10YR 3/3	Fine 50%	Fennic, mesic, matted	Very cloudy
F	25-32"	10YR 5/4 and 10YR 3/4	Medium to fine 60%	Stratified, fennic, matted, greasy, some roots, mesic	Muddy
F	32-40"	10YR 4/2 with thin band of 10YR 3/4	Medium and fine 60%	Fennic, matted, mesic, 10% wood	Cloudy
F	40-52"	10YR 4/4 + darker pockets	Fine and medium 60-70%	Fennic, matted, non-greasy, some wood	Cloudy
F	52-62"	10YR 4/4	Fine to medium 60%	Fennic, semi-decomposed but not greasy 10% wood	Cloudy
		10YR 6/3	-	Pockets of fine sandy loam	-
F	78-86"	10YR 3/4	Fine 40%	Fennic, well-decomposed	Muddy

Special characteristics: No mineral material encountered down to 105" with auger. Unusual to find Tamarack on such a deep bog.

Table 17. Profile description. Site 17. Wanham. Stratic mesic Fibrisol

Location: NW 10 77-3-6. 4.4 miles south of Wanham crossroads, east of road, 40 yds. back, almost under power line.

Vegetation:

Trees:	Picea mariana	D
Herbs:	Ledum groenlandicum	D
	Oxycoccus microcarpus	C
	Vaccinium vitis-idaea	F
	Maianthemum canadense	F
	Ribes sp	F
Macro-fungi:	Brown toadstools	F
Mosses:	Sphagnum warnstorfianum	C
	Dicranum undulatum	F
	D. polysetum	F
	Aulacomnium palustre	F
	Ceratodon purpureus	F
	Polytrichum juniperinum var. gracile	F
	Pleurozium schreberi	O
	Drepanocladus aduncus	O
Lichens:	Cladonia impexa	F
	Cladonia spp.	F
	Parmelia saxatilis	F

Horizon	Depth	Munsell colour(moist)	Fibres	Composition	Van Post Test
L	0-8"	10YR 5/4	Medium to coarse 90%	Loose, live and slightly decomposed Sphagnum	Almost clear
L	8-17"	10YR 6/6 and 10YR 5/4	Medium to coarse 90%	Sphagnic, some roots, non-greasy	Cloudy
L	17-25"	10YR 5/8	Medium 80%	Sphagnic, non-greasy	Cloudy
		10YR 3/4	Medium 60%	Small pockets	-
L(F)	25-31"	Mainly 10YR 5/6	Medium to coarse 80%	Sphagnic, matted, non-greasy, top 3" frozen	Cloudy
		10YR 3/2	Medium to fine 50-60%	2" band with some wood	Cloudy
F	31-35"	10YR 2/2	Medium to fine 50%	Slightly greasy, some roots	Muddy
F	35-41"	5YR 3/4	Fine 60%	Greasy, some wood	Muddy
F	41-47"	10YR 4/4	Coarse to fine 70%	Dominantly fennic, slightly greasy, some wood	Cloudy
F	47-57"	5YR 3/3	Medium to fine 60%	Fennic, slightly greasy, 10% wood	Muddy

Special characteristics: Recent burn, medium cover regeneration to about 6 feet in height. Relatively dry surface. 1964 dig revealed no substratum at 80" depth.

Table 18. Profile description. Site 18. Wembley. Unic Humisol

Location: NE 21 71-8-6. On highway, 100 yds. west of La Glace road, south side of road, 70 yds. south of "La Glace" highway sign.

Vegetation:							
Mainly	Herbs:	Carex sp	D	With clumps of	Trees:	Salix spp	F
		Grasses	O		Herbs:	Epilobium gracile	O
		Epilobium sp	O			Grasses	O
						Ranunculus occidentalis	O
						Solidago sp	O
						Erysimum inconspicuum	O
						Rumex sp	O

Horizon	Depth	Munsell colour(moist)	Fibres	Composition	Van Post Test
H	0-6"	10YR 3/1	Fine 30%	Fennic, greasy, humic, many roots	Muddy
H	6-22"	10YR 2/1	Fine 10%	Fennic, fine granular, some roots and clay, humic	Muddy
H	22-30"	10YR 2/1	Fine <10%	Fennic, humic, fine granular, some clay	Muddy
H	30-40"	10YR 3/1	Virtually none	Occasional sedge remains, higher clay content, humic	Muddy
H/Ah	40-48"	10YR 2/2	Medium and fine 20%	Fennic, high mineral content, massive, humic	Muddy
-	At 48"	-	-	Mineral substratum, clay	-

Special characteristics: Bog crosses road and site is drier where sampled than on north side of road (earlier sere?). No mosses observed near dig.

Table 19. Profile description. Site 19. Whitecourt. Mesisol

Location: SW 19 59-11-5. 2.8 miles south on highway from Whitecourt downtown junction, 25 yds. back into bush from telegraph poles. 25 yds. SW of #43 highway sign, going south.

Vegetation:

Trees:	Picea mariana	D	Mosses:	Sphagnum warnstorfianum	CoD
	Larix laricina	O		Pleurozium schreberi	CoD
Herbs:	Equisetum sp	A		Ptilium crista-castrensis	LD
	Ledum groenlandicum	F		Tomenthypnum nitens	C
	Maianthemum canadense	F		Dicranum polysetum	F
	Habenaria viridis	F		Aulacomnium palustre	O
	Menyanthes trifoliata	F		Polytrichum juniperinum	O
	Caltha palustris	F		Ceratodon purpureus	O
	Campanula sp	F	Lichens:	Peltigera aphthosa	F
	Carex sp	F			

Horizon	Depth	Munsell colour(moist)	Fibres	Composition	Van Post Test
L	0-3"	-	-	Loose Sphagnum, live	
L	3-8"	10YR 3/2	Coarse 70-80%	Partially decomposed mosses, many roots	Cloudy
F	8-20"	10YR 3/2	Medium to fine 50%	Non-greasy, some wood	Muddy
F	20-32"	10YR 3/3	Fine 50%	Slightly greasy, some wood	Muddy
F	32-44"	10YR 3/2	Fine 40%	Greasy, some wood	Muddy
F	44-60"	10YR 3/2 with 10YR 6/3	Fine 40-50%	Slightly greasy, pockets of silty loam	Muddy
Ah	60-63"	10YR 3/1	-	Dark clay substratum containing humic materials	-

Special characteristics: Much surface water present. Adjacent areas mainly on sand. Good stand of Black Spruce to height of 40 feet. Botanical origin of material from 8-60" was uncertain, perhaps mucinic.

Table 20. Profile description. Site 20. Winterburn. Terric stratic mesic Fibrisol

Location: Three-quarters of a mile north of highway, west side of road, sampled in road cut.

Vegetation:

Trees:	Picea mariana	D
	Larix laricina	A
	Salix spp	C
	Betula spp	C
Herbs:	Ledum groenlandicum	A
	Carex spp	C
	Epilobium angustifolium	LC
	Vaccinium vitis-idaea	F
	Oxycoccus microcarpus	F
Mosses:	Tomenthypnum nitens	D
	Ptilium crista-castrensis	F
	Polytrichum juniperinum	F
Lichens:	Cladonia fimbriata	LF

Horizon	Depth	Munsell colour(moist)	Fibres	Composition	Van Post Test
L	0-4"	5YR 3/2 and 4/2	Medium to coarse 95%	Undecomposed feathermosses with some sedge, lichen, etc. (This sample taken 30 yds. west of road cut).	
L	4-12"	5YR 4/8	Medium to coarse 90%	Undecomposed mosses	Clear
F	12-14"	5YR 3/4 and 10YR 2/1	Medium and fine 50%	Mesic, mainly mucinic, greasy	Cloudy
L	14-18"	5YR 3/4	Medium 80%	Mucinic with some fennic fibres, some roots	Almost clear
L/F	18-24"	5YR 3/3 5YR 3/2	Medium, some fine 60-70% -	Mainly mucinic. 1/2" inclusion of mesic material with evidence of burning	Cloudy
L/F	24-38"	5YR 3/4 and 5YR 3/3	Medium to fine 60-70%	Variable stratified material, mucinic with some fennic. Pockets of coarse fibred 90% undecomposed feathermoss present	Slightly cloudy
Limnic	38-40"	10YR 6/3 and 10YR 3/1	Fine 30%	Fennic, with shells and diatomaceous earth, calcareous, some wood, no detectable mucinic material	-
-	40-48"	10YR 3/1	Fine 20-30%	Heterogeneous woody (10%) layer with shells and other mineral material, sulphurous smell	-
	At 48"	-	-	Loam to clay-loam mineral substratum	

Special characteristics: Water coming in at about 36". Some evidence of burn, with strong regeneration, fairly dense cover of Spruce. Sampled from ditch-cut, has had human interference for a long time.

(iii) Meridian Fibrisol

This area has a smaller annual precipitation (38 cm.), with 23 cm. falling during the summer and 15 cm. during the winter. It has a lower mean annual temperature of 0.6°C and a mean annual frost-free period of about 60 to 75 days. The site was chosen for contrast as a Fibrisol, and because it had a permanently frozen horizon within it.

2. Sampling sites for general study

Seventeen further sites, giving a total of nine Fibrisols, seven Mesisols and four Humisols, were sampled in conjunction with the Alberta Soil Survey. A map showing their distribution is included, (Fig. 1, page 23). Physical, chemical and botanical analyses only were done on these samples, for the purpose of correlating organic soil sub-group and vegetation. The organic soil descriptions are given in Tables 1-20 (pages 22-46).

(i) Soil descriptions

The latest classification of organic soils (Ehrlich 1965) is based on the use of a control section which, for unconsolidated peat extends down 60 inches from the surface. The least decomposed type of organic soil is defined as a Fibrisol, whilst a generally well-decomposed bog is referred to the Humisol Great Group, with an intermediate Group called Mesisols. Where horizons other than the main type occur, descriptive adjectives are used before the name of the Great Group when naming the soil type. A part of the National Soil Survey Committee report on the Classification of Organic Soils is reproduced here for convenience. The colour descriptions refer to Munsell Colour Charts.

Definitions and Criteria of Organic Soils

A. Control Section (assumed to include the zone of maximum microbiological activity).

Thickness of control section in organic soils is 40 inches from the surface if the organic material is consolidated or 60 inches if it is unconsolidated. Consolidation of peat is the result of subsidence through drainage, cultivation, pasturing, etc. The control section may extend into the underlying mineral soil or bedrock substratum.

B. Kinds of tiers and layers

For classification purposes, the control section has three tiers - surface, subsurface and bottom, each of which may have one or more kinds of layers. The tiers and layers are as follows:

1. Surface tier is the top 12 inches of consolidated or 18 inches of unconsolidated organic material. (This thickness of peat is permissible with mineral soils.) This tier, except the loose surface litter, is included with the classification of Terric and Lithic types having less than 24 inches of consolidated or 36 inches of unconsolidated organic material. Where these thin peats occur they are classified on the dominant type of peat modified by other types if present in significant proportions.

2. Subsurface tier is immediately below and is equal in thickness to the surface tier. This tier establishes the Great Group classification if no mineral substratum is present. If a mineral substratum occurs in this tier, the peat in this tier is included and classified with the surface tier on the basis of the dominant kind of peat.

3. Bottom tier is that portion extending from the subsurface tier to the bottom of the control section. This portion may range from totally organic to totally mineral. The organic material in this tier, if in significant proportions, establishes or assists in establishing the Subgroup classification.

In summary, tiers in the control section are as follows:

	Consolidated	Unconsolidated
Surface tier	0-12"	0-18"
Subsurface tier	13-24"	19-36"
Bottom tier	25-40"	37-60"

4. Diagnostic layers

Fibric - least decomposed stage.
It must have more than 2/3 fibers (140 mesh or >0.1 mm) total mass. More than 50 percent of the fibers must be well preserved as to not change chroma when rubbed wet or will resist disintegration or becoming greasy.

Mesic - intermediately decomposed stage.
It has a fiber content between 1/3 and 2/3 in the total mass over 50 percent of the fibers will decrease at least one unit in chroma when rubbed wet, or if the fiber content exceeds 2/3 of the total mass and does not change color upon rubbing then over 50 percent of the fibers are easily broken down or become greasy when rubbed wet.

Humic - most decomposed stage.
It must have less than 1/3 fiber in the total mass. It must not change color when rubbed wet, and the sodium pyrophosphate extract on white filter paper is lower in value and higher in chroma than 10YR 7/3.

5. Other layers

Unic - consisting of one diagnostic mesic or humic layer throughout the organic section in the subsurface and bottom tiers or in shallow peats throughout the organic section of the surface and subsurface tiers.

Fennic - dominantly fibric fen peat in the subsurface tier or dominantly fibric fen peat in the surface and subsurface tiers if a mineral substratum occurs in the subsurface tier.

Mucinic - dominantly fibric moss peat in the subsurface tier or dominantly fibric moss peat in the surface and subsurface tiers if a mineral substratum occurs in the subsurface tier.

Stratic - two or more kinds of diagnostic peat layers in significant proportions* in the subsurface and bottom tiers or in the surface and subsurface tiers if the mineral substratum occurs in the subsurface tier. Twelve kinds of Stratic types may occur: Stratic Mesic Fibrisol; Stratic Humo-Mesic Fibrisol; Stratic Fibric, Mesisol, etc. Where all diagnostic layers occur in significant proportions* they are arranged in the order of increasing amounts. The first named of three has a suffix "o" in place of "ic" to reduce discordance of names. The "ic" remains when only one modifier is used.

Luvic - an illuvial layer in the subsurface tier or in the upper bottom tier with more colloidal material than the underlying peat. This layer has fine materials with a greasy, glossy appearance in fractions and in root channels.

Clasto - a layer(s) of significant proportions with 30-70 percent mineral material in the organic part of the control section.

Limno - a significant layer(s) (>2 inches) of marl, diatomaceous earth, sedimentary peat, bog iron, possibly others.

Cumulo - alternate layers of organic and mineral materials.

Cryo - permanently frozen within the control section.

Terric - unconsolidated mineral substratum with less than 30 percent organic matter occurring in the subsurface of bottom tiers.

Lithic - consolidated mineral substratum (bedrock) occurring in the subsurface or bottom tiers.

*Significant proportions in peats extending into the bottom tier, is more than one-sixth of the total mass for each diagnostic type in the subsurface and bottom tiers, and of similar amounts for those peats extending only into the subsurface tier. The dominant type should be greater than one-third of the total mass in the subsurface tier or in the surface and subsurface tiers if a mineral substratum occurs in the subsurface tier.

(end of quotation)

(ii) Vegetation descriptions

The taxonomic and vernacular names of the higher plants found during this study are included below:

1.	Aster puniceus L.	Purple-stemmed Aster
2.	Betula spp.	Birch species
3.	Caltha palustris L.	Marsh Marigold
4.	Campanula sp.	Harebell
5.	Carex spp.	Sedge species
6.	Drosera rotundifolia L.	Round-leaved Sundew
7.	Empetrum nigrum L.	Crowberry
8.	Epilobium angustifolium L.	Fireweed
9.	Equisetum sp.	Horsetail
10.	Eriophorum gracile Koch	Cotton Grass
11.	Eysimum inconspicuum (S. Wats.) MacM.	Small-flowered Rocket
12.	Galium boreale L.	Northern Bedstraw
13.	Habenaria viridis (L.) R.Br.var.bracteata (Muhl.) A. Gray	Bracted Orchid
14.	Larix laricina (Du Roi) K. Koch	Larch or Tamarack
15.	Ledum groenlandicum Oeder	Common Labrador Tea
16.	Maianthemum canadense Desf.var.interius Fern.	Wild Lily of the Valley
17.	Mentha arvensis L. var.villosa (Benth.) S.R. Stewart	Wild Mint
18.	Menyanthes trifoliata L.	Buck-bean
19.	Oxycoccus microcarpus Turcz.	Small Bog Cranberry
20.	Parnassia montanensis Fern. & Ryob.	Grass-of-Parnassus
21.	Picea glauca (Moench) Voss	White Spruce
22.	Picea mariana (Mill.) BSP.	Black Spruce
23.	Potentilla palustris (L.) Scop.	March Cinquefoil
24.	Ranunculus occidentalis Nutt.	A Buttercup
25.	Ribes sp.	Wild Currant
26.	Rubus acaulis Michx.	Dwarf Raspberry

27.	Rumex occidentalis S.Wats.var.fenestratus (Greene) Le Page	Western Dock
28.	Salix spp.	Willow species
29.	Scirpus hudsonianus (Michx.) Fern.	A Bulrush
30.	Scutellaria galericulata L.	Common Skullcap
31.	Solidago sp.	A Goldenrod
32.	Vaccinium vitis-idaea L.var.minus Lodd.	Cowberry

The vegetation at the sites was identified using the Flora of Alberta by Moss (1959), except for the mosses which were sent to Dr. C. Bird at the University of Calgary, who kindly speciated them for me. An assessment of the relative proportions of each species in each botanic stratum was made using the following standard nomenclature:

D = dominant

CoD = co-dominant

A = abundant

C = common

F = frequent

O = occasional

R = rare

B. METHODS

1. Sampling and laboratory preparation

(i) Dates of sampling

In an effort to record some seasonal effects the following major samplings were made:

Granada Humisol	August 5		October 22
Evansburg Mesisol	June 13		September 15
Meridian Fibrisol		August 20	

At the time of the first sampling at Evansburg the ground had only just thawed, and at the last sampling of Granada, ice had appeared within the profile. The Fibrisol was unusual as it had a frozen horizon in mid-summer, and it was presumed that this was therefore permanent (Odynsky pers. comm.).

(ii) Samples

A sample of about 800 grams was taken from each horizon and brought back to the laboratory in a sealed polythene bag. These samples were used as soon as possible for duplicate determinations of water-holding capacity, pH and fibre content. The residues were air-dried, ground to pass through a 2 mm sieve and stored in air-tight glass containers ready for nitrogen, cation exchange capacity and pyrophosphate determinations. Approximately 2 grams from each sample were hand-ground with a porcelain mortar and pestle and used to estimate carbon. The three profiles selected in each pit were sampled separately for microbiological work, water content and organic matter determinations. Approximately 100 grams from each horizon were aseptically collected into sterile screw-cap jars, using 95% ethanol swabs to clean the sampling instruments. These samples were all utilised within 24 hours of collection.

(iii) Method of dilution

The aseptically taken A, B and C samples were serially diluted in sterile water blanks to 10^8 for the various microbiological analyses. As peat is a very variable substance and as the actual weight of organic matter was usually less than one-tenth of the wet sample, it seemed more practical to use a 10 gram sample added to a 90 ml sterile water blank rather than 1 gram in 99 ml, as the initial dilution. In fact this was borne out in the preliminary tests, when a wider range of bacterial types grew from a 10 gram in 90 ml initial dilution. Also bearing in mind the necessity for sufficient shaking to effectively disperse and mix the material, as opposed to the tendency of fungal filaments to fragment when shaken, it was decided that a

compromise had to be made. The following method was therefore used throughout the work:

1. 10 g of sample was aseptically weighed and transferred to a 90 ml sterile water blank, (10^{1} dilution).
2. Shaken vigorously 50 times by hand.
3. Subsequent dilutions made with sterile 10 ml pipettes, transferring 10 ml to 90 ml water blanks.
4. These were shaken 20 times each and the next transfer made immediately.
5. When plating, the sample bottle was shaken 20 times and then used for all platings necessary from that dilution, ensuring uniformity of shaking for all counts.

2. Soil properties

(i) Water content

Approximately 10 g of the A, B and C samples were accurately weighed and dried at the standard 105-110^{o}C for 24 hours, weighed again and the oven-dry weights checked after a further 4-6 hours drying at the same temperature.

(ii) Water-holding capacity

This was estimated according to the method outlined below: A handful of the bulk sample was placed in a 500 ml beaker and excess water added. It was allowed to soak for 10 minutes, meanwhile stirring vigorously to remove air and disperse clods. The whole mass was then put into a glass funnel plugged beneath with glass wool, (but no filter paper). A watchglass was placed on top of the funnel to prevent evaporation, and the saturated peat allowed to drain for one hour. An exactly weighed sample of about 10 g was then taken from the middle of

the drained mass, and oven-dried at 105-110°C for 24 hours as in (i). The ratio of peat to water was then calculated.

(iii) Organic matter content

The samples used to estimate water content (i) were subsequently put in the furnace at 400°C for 4 hours to burn off the organic matter (Ball 1964) and results expressed as a percentage.

(iv) Percentage fibre

In the field this was estimated by sight and by rubbing the material between the fingers; in the laboratory by weighing the residue left on a 100 mesh sieve after dispersing with sodium hexametaphosphate (Calgon).

(v) Degree of decomposition - Van Post test

This is a field test performed by squeezing a handful of the peat sample and noting the clarity of the expressed water. The following guide to decomposition is used: (Wicklund 1963)

Clear	Undecomposed
Cloudy	Slightly decomposed
Very cloudy	Moderately decomposed
Muddy	Well decomposed
All passes through fingers	Organic ooze

(vi) Degree of decomposition - Pyrophosphate

(a) Index: extracted with 0.1 M sodium pyrophosphate. Optical density read at 420 mu. Index = O.D. x 5.

(b) Test: comparing the colour developed on chromatographic paper, after extraction with saturated sodium pyrophosphate, with Munsell colour chips. (Farnham and Finney 1965).

(vii) pH

This was determined in saturated paste in water on moist samples, soon after arrival in the laboratory.

(viii) Nitrogen

The standard macro-kjeldahl method was used.

(ix) Carbon

This was performed by dry combustion in a Leco induction furnace.

(x) Cation Exchange Capacity

Determined as usual by leaching with ammonium acetate and then by the method of displacement and distillation for adsorbed ammonium, (ASA. Methods of soil analysis 1965).

3. Bacterial analyses

The lack of previous peat microfloral investigations meant that many preliminary tests on media, dilutions, lengths of incubation, etc. had to be carried out to find the most suitable procedures for present usage. It also meant that some methods were discontinued during the course of the work, when their contribution was considered to be negligible.

(i) Enumeration

Nutrition: Plate counts on four different solid media were made to determine the nutritional needs of the dominant bacteria. These agar media, (details of the preparation of which are contained in Appendix I), contained the following ingredients:

Media / Ingredients	#1	Basal	Plate Count	B12
Tryptone	+		+	+
Glucose		+	+	
Yeast extract			+	+
Salts		+		+
Vit B12				+

Numbers of psychrophiles, mesophiles and thermophiles growing on the four nutritional media in all the subsampled horizons were reduced to an oven-dry weight basis.

Dilutions and length of incubation: Some preliminary trials were made to determine the most practical dilutions, and tests on the most suitable lengths of incubation were made during the first major experimental run. An average of counts made from two dilutions being statistically more acceptable, (James and Sutherland 1940a), 0.1 ml of two dilutions were used for each count throughout.

Temperatures: Duplicates of all plates were incubated at 15^{o}, 28^{o} and 50^{o}C respectively.

Replication: For the first experimental run, using the Mesisol samples, three replicates of each of the three subsamples (A, B and C), were used at each temperature and each dilution. A statistical analysis of the results showed that in 90% of cases there was no significant difference between the replicates, and in 74% of cases there was no significant difference between subsamples. In the second Granada and the Meridian experimental runs, time did not permit of such an extensive treatment and thus replication within subsamples was omitted.

Organic soil extract: A preliminary test was set up to determine whether the use of peat extract media would be useful in enumerating peat bacteria. The following peat extract media were made, with and without additions of yeast and dibasic phosphate as recommended by James (1958):

Component	Peat extract	P.E. + Phosphate	P.E. + Yeast	P.E. + Phosphate + Yeast
Peat extract	100 ml	100 ml	25 ml	25 ml
Dibasic phosphate		0.02 g		0.005 g
Yeast			0.1 g	0.1 g
Agar	1.5 g	1.5 g	1.5 g	1.5 g
Water			75 ml	75 ml

Five replicates of a 10^4 dilution of a Mesisol peat sample were poured, using 1.0 ml of sample and 20 ml of medium.

As this was unsuccessful, (see results), probably due to the pH factor, other trials using soil and peat extracts of modified pH's were made up, to see if these would be more successful in supporting the growth of peat micro-organisms. The following six extracts were made:

(i)	600 g	peat-Mesisol	horizon	IV A	+	1500	ml	water
(ii)	400 g	"	"	"	+	"	"	"
(iii)	200 g	"	"	"	+	"	"	"
(iv)	600 g	Greenhouse	soil		+	"	"	"
(v)	400 g	"	"		+	"	"	"
(vi)	200 g	"	"		+	"	"	"

These were autoclaved for 20 minutes, then placed in a large Büchner funnel with no filter paper. The expressed water was filtered through a Büchner filter pump and the amount of extract measured. Then 600 ml of each extract was taken and divided into three portions, treated as follows:

I pH not altered

II pH brought to 6.8 with $\frac{N}{10}$ NaOH

III pH brought to 4.8 with $\frac{N}{10}$ HCl

Three grams of agar were added to each and the 18 flasks autoclaved for 20 minutes. Ten pour plates from each medium, using 1.0 ml of dilution 10^3 of Mesisol IV A and dilution 10^5 of greenhouse soil, with five replicates of each were then dispensed.

(ii) Identification

The types of bacteria present were tentatively identified using standard methods employed in bacterial taxonomy. Determinations were made

on each medium and each horizon, to compare the variation of horizons and sites, and also the relative effectiveness of the media. Precise identification was made of 67 randomly chosen specimens.

(iii) Cytophaga

The plate count medium was found to be superior in bringing up Cytophaga species, and they were therefore counted from these plates. An attempt made to count them on yeast plates met with no success because of the occlusive behaviour of the many other bacteria present.

Detailed descriptions of 13 of the Cytophaga found in the Granada bog were made. Some of these organisms were assessed for their ability to digest cellulose, using filter paper on yeast plates, (Pramer and Schmidt 1964).

(iv) Chromobacterium

Counts of psychrophilic and mesophilic Chromobacteria were taken from the plate count media. They attracted interest because of their singular presence in humic horizons, therefore a detailed study of 20 specimens was made. This included work on their temperature range, microscopical characteristics and cultural behaviour, (Bergey 1957, Corpe 1953). The chromobacters were tested as to nutritional class, and for proteolysis using a standard nutrient gelatin, (Leifson 1956, Sneath 1956). Action on glucose was investigated using Board and Holding's medium (1960), and denitrification and iron reduction employing the media quoted in 5 (ii) and 5 (v).

4. Fungal analyses

(i) Enumeration

Preliminary tests indicated that the weights of peat samples needed for soil plates (Warcup 1950), would be too small to be weighed

out for large numbers of determinations. Therefore only soil dilutions were used to estimate numbers of fungi present in the samples. The preliminary tests again showed the most useful dilutions, lengths of incubation and necessary replication for the two types of agar pour-plates used, Rose Bengal-Streptomycin (Martin 1950), and Potato dextrose-Novobiocin (Butler and Hine 1958). Psychrophilic and mesophilic counts were made on each profile, and although thermophilic fungi were not expected (Alexander 1961), a test was run on the Mesisol. Numbers were reduced to an oven-dry weight basis.

(ii) Identification

Fifty seven fungi were picked out as different by headmark, and sent to Dr. A. E. Peterson at the Microbiology Research Institute in Ottawa, who kindly did the generic identifications.

(iii) Immersion tubes

The presence of actively growing fungal filaments in the Mesisol and Humisol was tested by using immersion tubes (Chesters 1940, 1948). Plastic tubes 13 mm wide and 10 mm long had eight 2 mm diameter holes regularly spaced along their length, through which fungal filaments could grow. The tubes were wrapped in silver foil, sterilised, filled with Rose Bengal-Streptomycin agar and capped with foil. In the field the foil wrapping was removed, and duplicate tubes were inserted horizontally at intervals down the profile. The foil caps remained in place to preserve the sterility of the top of the medium, and to make the tubes easily visible for later extraction. After 20 days incubation in the soil the tubes were removed and, immediately on return to the laboratory, one of each pair was aseptically sliced longitudinally and the other into eight horizontal pieces. These slices were left to incubate and

fruit on Rose Bengal plates for one week. An estimate of the numbers, and correlation of types with the dilution method, were attempted.

5. Physiological studies

An investigation of the part played by micro-organisms in the conversion of nitrogen compounds within peat was undertaken. The following processes were studied in the 'A' series of profiles:

Nitrification	NH_4	-----> NO_2 ----->	NO_3
Denitrification	NO_3	-----> NO_2 ----->	gas
N-fixation	N_2	----->	bacterial protein
Ammonification	Plant protein	------>	NH_3

All MPN numbers from these studies were corrected for soil moisture, on an oven-dry weight basis.

(i) Nitrification

All horizons were tested for the presence of organisms such as Nitrosomonas and Nitrobacter, which respectively carry out the two reactions effecting nitrification: -

$$NH_4 \xrightarrow{\text{Nitrosomonas}} NO_2 \xrightarrow{\text{Nitrobacter}} NO_3$$

1.0 ml aliquots of each of several dilutions of peat were pipetted into five replicate tubes of an ammonium broth (Medium A, see Appendix I) to determine the MPN of Nitrosomonas, and into nitrite broth (Medium B) for Nitrobacter (Waksman 1932). Incubation was at room temperature for nine days. The presence of nitrite was tested with Trommsdorf's reagent, and that of nitrate with diphenylamine and a negative Trommsdorf test.

(ii) Denitrification

An exactly similar inoculation of dilutions as in 5 (i) was made into a nitrate broth, modified by the addition of vitamin B12 found to stimulate growth, (Allen 1959. See Appendix I), to determine the MPN of denitrifiers. NO_2 and NO_3 were read as before.

(iii) Nitrogen fixation

A similar inoculation into nitrogen-free mannitol broth was made to determine the numbers of Azotobacter and other nitrogen-fixing bacteria. Growth was noted by turbidity of the medium, and microscopic smears and nigrosin-stained mounts of the cultures were examined.

(iv) Ammonification

Casein broth (0.5%) was used as the protein source for MPN counts of ammonifiers present in the peat samples. The same method as in 5 (i) was followed, growth was seen by turbidity of the medium, and ammonia was detected with Nessler's reagent.

(v) Iron reduction

Iron reduction by peat micro-organisms was estimated in a ferric phosphate medium (Panter 1964). 1.0 ml aliquots of several dilutions were added to five replicates of broth tubes. Reduction was characterised by the production of a dark green gel or a greenish solution after seven days. A pilot run to determine dilutions required, to check replication of results and to try out two handling procedures was attempted first of all:

Method A: 10^1 dilution shaken 50 times; 10 ml withdrawn immediately with suspended matter to make the 10^2 dilution.

Method B: 10^1 dilution shaken vigorously for two minutes (about 200 times); sediment allowed to settle for 5 minutes before samples, without sediment, were withdrawn to make further dilutions. Further dilution proceeded as in 1 (iii) above.

Method A was adopted, for reasons to be stated later (see results).

6. Other microbial analyses

(i) Actinomycetes

Actinomycete numbers were estimated from bacterial plates, (see 3 (i) above), and from special egg albumen agar plates (Waksman 1959). 0.1 ml of the A, B and C replicate samples of each horizon were incubated for six days at room temperature.

(ii) Algae

A modified Bristol's solution (Gerloff, Fitzgerald and Skoog 1950), and a modified Chu's solution (Pramer and Schmidt 1964), were used to count total algae and Cyanophyceae (blue-green algae) respectively. Only the top horizons of the Humisol and the Mesisol were tested, and the green growth was noted and microscopically examined.

(iii) Myxomycetes

No myxomycetes were observed in the field, but nevertheless an attempt was made to isolate them by Kitzke's method (1952), using the Mesisol samples. A three-day-old culture of Aerobacter aerogenes was skimmed off of its original plate and suspended in sterile water. Eight screw-cap jars were half-filled with the loosely pulverised peat samples, and the bacterial suspension sprinkled liberally on them, taking care not to inundate the samples. The cap was loosely replaced on the jars, and they were left at room temperature for three days and examined again after one and two weeks for plasmodia and fruiting bodies.

(iv) Contact slides

In order to demonstrate the inter-relationships of some of the soil microflora, the Rossi-Cholodny contact slide technique was tried, (Rossi et al. 1936, Brown 1958, Starkey 1938, Cholodny 1930).

Sterilised glass slides were inserted at intervals down the Humisol and Mesisol profiles and left for 20 days. They were then carefully removed, preserving intact the soil on the upper side, brought back to the laboratory and allowed to dry. The excess peat was gently removed from the 'good' side, and the slide, with the few adhering particles, stained with lacto-phenol cotton blue to emphasize the actinomycete and fungal filaments and the bacteria. They were then observed under the microscope.

(v) Antiobiotic

One bacterium isolated was suspected of producing an antibiotic and was tested in the following manner. Cultures were grown on #1 broth for 24 hours on the shaker, then spun down at 9000r for 20 minutes and the supernatant kept. #1 plates were poured with a top layer of one-third strength plate count (0.5% agar) and inoculated with a broth culture of Arthrobacter globiformis. This was allowed to set, and dilutions of the supernatant from the bacterium impregnated onto sterile discs, were placed in the middle of the plates. They were incubated at room temperature and read after 24 hours, by measuring the radius of the zone of inhibition.

RESULTS AND DISCUSSION

A. VEGETATION AND SOIL CHARACTERISTICS

1. Vegetation and soil type

The vegetation descriptions (Tables 1-20 pages 24-46) show that Picea mariana (black spruce) dominates at 14 of the sites, including all but one of the Fibrisols and Fibric Mesisols, half of the other Mesisols, but only one of the four Humisols. White spruce (Picea glauca) is the dominant in the Magnolia Fibrisol and the Drayton Valley Humisol, and the Peers Humic Mesisol is unusual in supporting a dense stand of Tamarack (Larix laricina). The Unic Mesisol at Gunn and the Unic and Terric Humisols sustain careceta with a few Salix appearing at the Wembley site.

There is a trend for the wet Fibrisols and Fibric Mesisols to have a restricted number of herbaceous plants (3-5 commoner species per site), whilst the drier conditions of the more humified bogs support a more varied flora (6-8 species per site). The differences in the floristic composition are very noticeable, as shown in Plates 4 and 5 (pages 66 and 67). The wet Fibrisols have a limited tolerant flora comprised mainly of Ledum, Vaccinium and Oxycoccus. Although present at most sites the dominance of these three species seems to diminish in competition with a number of herbs able to colonize at the Mesisol and Humisol stages of the sere. Carex assumes its greatest importance in certain Humisols and in the Unic Mesisol, and it is accompanied by a third group of herbs. These patterns are clearly shown in Figure 2, where more significant botanical associations have been indicated by assembling the Fibrisols and Fibric Mesisols together, and by abstracting the Carex bogs from the Mesisol and Humisol Great Groups.

The moss species follow a similar pattern, the wetter Fibrisols are characterised by Sphagna, and as the drier stages are approached, "feather" mosses such as Ptilium crista-castrensis, Tomenthypnum nitens and Aulacomnium palustre gradually take precedence. However in the sedge bogs the only moss encountered is Drepanocladus aduncus.

These observations on the botanical composition are in agreement with the work of Moss (1953). Figure 3 indicates his theory of the seral succession in Alberta bogs. Superimposed upon this is an hypothesis of a possible sequence of peat development, taking into account the macroflora at the sites, the botanical composition of the peat strata within the bogs and the current classification of these areas. The physical and chemical characteristics will now be shown to corroborate this hypothesis.

Plate 4. Granada Humisol Surface vegetation

Ledum groenlandicum, Oxycoccus microcarpus, Equisetum sp, various sedges and Tomenthypnum nitens

Evansburg Mesisol Surface vegetation

Young Picea mariana, Vaccinium vitis-idaea, Ledum groenlandicum, Eriophorum gracile, Sphagnum warnstorfianum and various "feather" mosses

Plate 5. Meridian Fibrisol Surface vegetation

Equisetum sp, *Ribes* sp, *Sphagnum warnstorfianum*, *S. recurvum* and various "feather" mosses

Figure 2. Herbs - Percentage of times present in each peat type

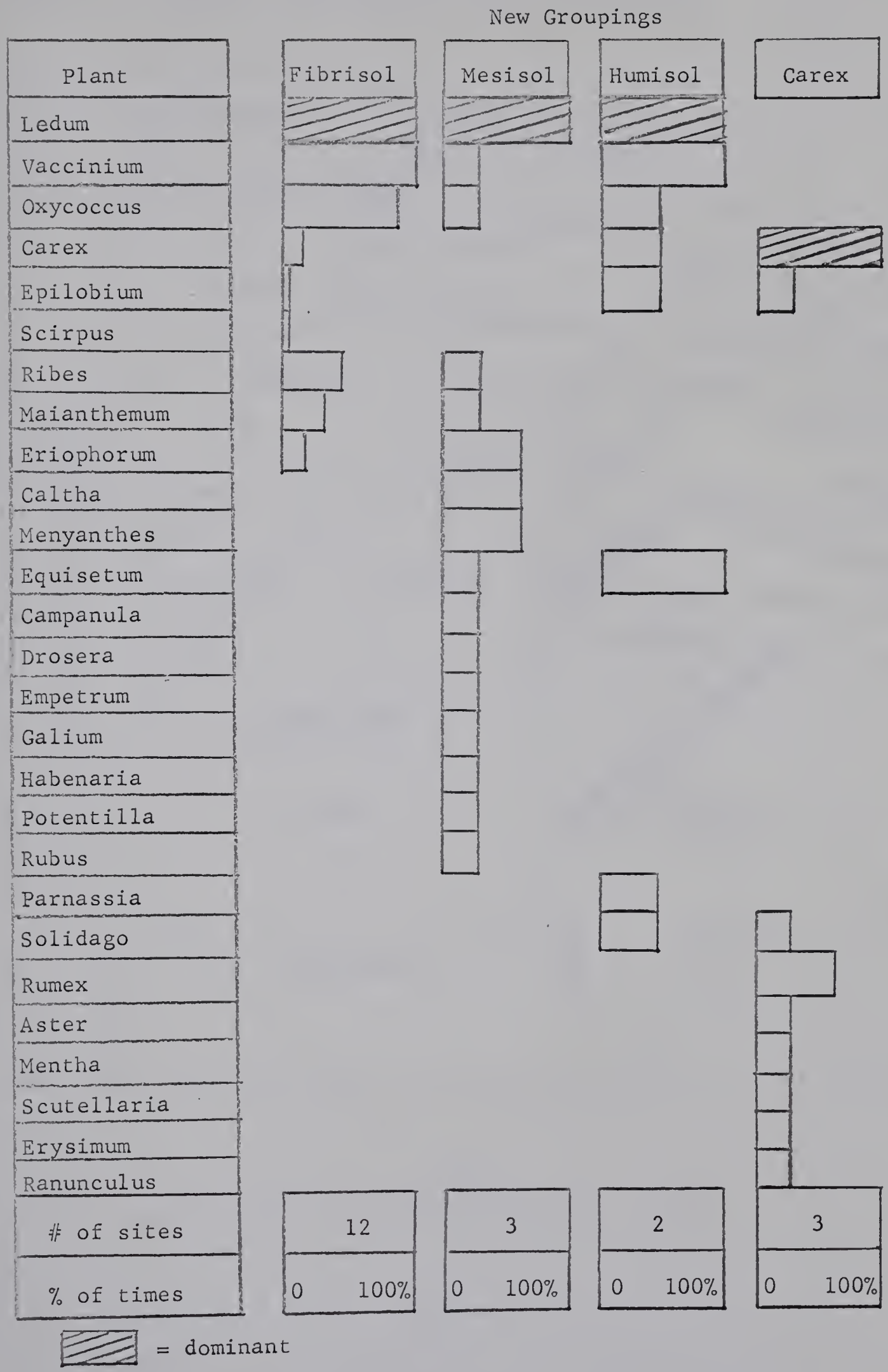
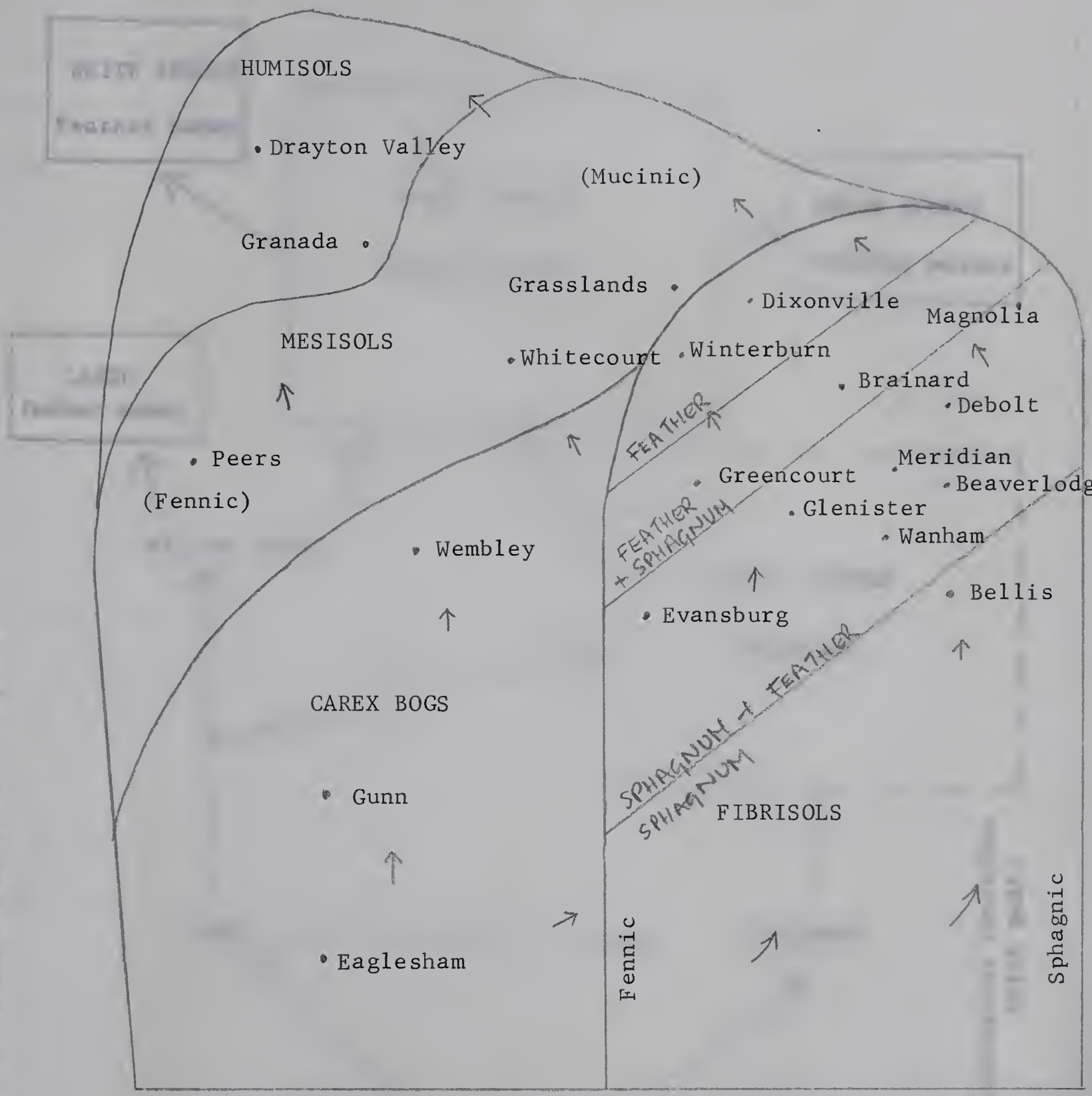


Figure 3. overlay. Hypothesis of peat development
Current sere of bogs studied is indicated

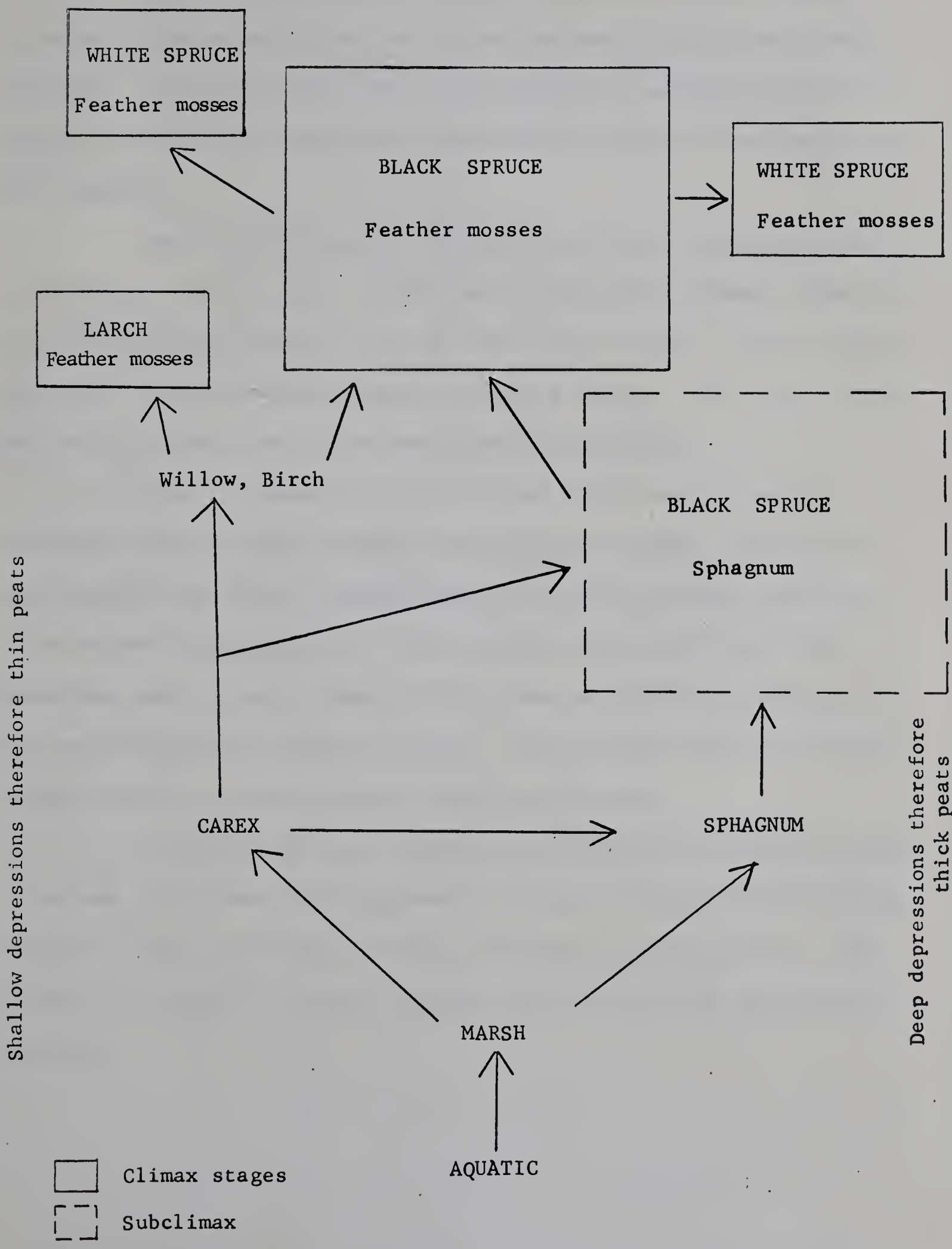


→ = Direction of normal development of bogs

MESISOLS
Peers
(Fernie)
Wembley
CHERNOZEMS
Grande Prairie
Beaverlodge
Dawson Creek
Fort St. John
Hudson Hope
Chetwynd
Tumbler Ridge
Mackenzie
Prince George
Quesnel
Williams Lake
Alexis Creek
Anahim Lake
Bella Coola
Kitimat
Terrace
Prince Rupert
Queen Charlotte City
Masset
Sandspit
Port Hardy
Port Alice
Port McNeill
Alert Bay
Campbell River
Courtenay
Duncan
Victoria
Sooke
Port Renfrew
Lake Cowichan
Ladysmith
Nanaimo
Gabriola
Powell River
Sechelt
Gibsons
Pender Harbour
Egmont
Whistler
Pemberton
Lillooet
Lytton
Ashcroft
Cache Creek
Clinton
Merritt
Princeton
Hope
Chilliwack
Abbotsford
Langley
Surrey
White Rock
Delta
Richmond
Vancouver
North Vancouver
West Vancouver
Burnaby
New Westminster
Port Coquitlam
Port Moody
Coquitlam
Pitt Meadows
Maple Ridge
Mission
Agassiz
Harrison Hot Springs
Kent
Chilliwack
Sardis
Vedder Crossing
Yarrow
Cultus Lake
Greendale
Rosedale
Popkum
Bridal Falls
Deroche
Lake Errock
Harrison Mills
Ruskin
Stave Falls
Hatzic
Dewdney
Mt. Lehman
Matsqui
Clearbrook
Abbotsford
Sumas
Aldergrove
Langley
Fort Langley
Cloverdale
Surrey
White Rock
Delta
Richmond
Vancouver
North Vancouver
West Vancouver
Burnaby
New Westminster
Port Coquitlam
Port Moody
Coquitlam
Pitt Meadows
Maple Ridge
Mission
Agassiz
Harrison Hot Springs
Kent
Chilliwack
Sardis
Vedder Crossing
Yarrow
Cultus Lake
Greendale
Rosedale
Popkum
Bridal Falls
Deroche
Lake Errock
Harrison Mills
Ruskin
Stave Falls
Hatzic
Dewdney
Mt. Lehman
Matsqui
Clearbrook
Abbotsford
Sumas
Aldergrove
Langley
Fort Langley
Cloverdale

Figure 3. Seral relationships in Alberta bogs

(after Moss 1953)



2. Physical and chemical characteristics

Table 21 indicates the range of some of the physical and chemical characteristics for the control section of the 20 peat bogs examined. By grouping the fibric types together, and abstracting the Carex bogs as before, much more significant groupings of the properties are obtained.

Group I, including the Fibrisols and Fibric Mesisols is seen to possess a thick L layer of relatively undecomposed sphagnic remains, high water-holding capacity, low pH, high fibre content, low ash content and low N content and consequently wider C/N ratios. This ties in very well with Farnham's work (see Farnham and Finney 1965).

Group II consists of the Unic and Humic Mesisols and the Humisols, without those existing under Carex at present. These have considerably shallower L layers, higher but still acid pHs, and a reduced water-holding capacity. They are more humified at depth and therefore have a greater range of fibre content within the profile and the percentage ash is slightly higher. The nitrogen content is a little higher and the C/N ratio narrower than the Fibrisols.

The sedge bogs are characterised primarily by having no fibric L horizon. They have a pH approaching neutral, a reduced water-holding capacity, lower percentage of fibres and higher percentage ash. Their content of nitrogen is higher, therefore the C/N ratio is appreciably narrowed.

Table 21. Ranges of selected physical and chemical characteristics for the control sections

Group	Bog	Dominant Moss	Depth of L	pH	WHC	% Fibre	% Ash	%N	C/N
FIBRISOLS									
Mesic	Bellis	Sphagnum	18"	3.4 - 6.2	5 - 17	47 - 86	7 - 17	0.7 - 1.9	20 - 59
	Beaverlodge	S + F	21"	3.9 - 4.7	7 - 19	60 - 91	2 - 15	0.8 - 1.3	39 - 52
	Debolt	Sphagnum	24"	4.1 - 7.6	6 - 13	44 - 91	5 - 9	0.7 - 2.2	21 - 60
	Magnolia	S + F	24"	4.3 - 5.3	8 - 16	71 - 87	3 - 12	0.8 - 1.4	35 - 50
	Meridian	Sphagnum	20"	3.5 - 4.6	5 - 16	47 - 87	2 - 12	0.7 - 3.0	16 - 63
	Wanham	S + F	31"	3.4 - 5.2	6 - 13	43 - 95	2 - 9	0.7 - 2.5	19 - 69
	Brainard	Feather	28"	3.5 - 5.2	7 - 15	78 - 90	2 - 11	0.5 - 1.1	42 - 94
	Dixonville	Feather	13"	4.6 - 5.5	4 - 14	60 - 81	3 - 31	0.8 - 1.2	34 - 83
	Winterburn	Feather	18"	4.3 - 7.6	6 - 16	64 - 89	10 - 23	0.6 - 1.8	21 - 61
MESISOLS									
Fibric	Evansburg	Sphagnum	7"	3.6 - 5.3	7 - 16	76 - 86	1 - 6	0.7 - 1.7	26 - 58
	Glenister	Sphagnum	10"	3.7 - 5.3	5 - 17	51 - 94	6 - 29	0.9 - 1.3	34 - 58
	Greencourt	Feather	16"	4.5 - 5.8	7 - 13	64 - 86	6 - 9	1.0 - 1.8	25 - 44
Fibric to Humic	Grasslands	Sphagnum	20"	3.8 - 6.3	7 - 16	67 - 92	6 - 14	0.6 - 1.2	36 - 60
Unic	Whitecourt	S + F	8"	6.3 - 7.2	5 - 12	39 - 90	10 - 19	1.0 - 3.0	13 - 27
Humic	Peers	Feather	2"	5.3 - 5.9	5 - 11	15 - 60	5 - 31	1.5 - 3.2	13 - 21
HUMISOLS									
Fibric	Drayton Valley	Feather	4"	5.3 - 6.3	5 - 7	41 - 80	10 - 20	1.1 - 1.3	25 - 34
Mesic	Granada	Feather	6"	5.6 - 6.1	2 - 10	31 - 84	6 - 30	1.0 - 1.3	25 - 40
Carex Bogs									
Mesic	Gunn	Drepanocladus	-	6.8 - 7.4	5 - 6	27 - 58	9 - 31	2.2 - 2.7	14 - 18
Humic	Wembley	-	-	4.9 - 6.8	3 - 4	23 - 74	14 - 43	2.2 - 3.8	12 - 13
Terric	Eaglesham	-	-	5.9 - 7.6	2 - 4	16 - 22	51 - 69	1.0 - 2.0	11 - 11

3. Major sampling sites

Tables 22-24 contain details of the organic matter, water and ash contents of all profiles at the three sites studied microbiologically. Table 25 shows various other physical and chemical data for these soils. All these properties are best viewed in conjunction with the ranges of properties exhibited by the soil Great Groups (Table 21).

The three peat sites chosen for detailed study show variations in field characteristics, and this was the reason for sampling three separate profiles at each site. Tables 22-24 show that the percentage water (wet weight basis) has the least variability of the characters, but when water is expressed on an oven-dry weight basis the anomalies become apparent.

The pattern of water distribution down the profiles varies with the sampling date, this could be due either to season, or to the weather conditions prior to each sampling. As was expected, the amounts of organic matter are very high in the Mesic Fibrisol and the Fibric Mesisol, and the latter has only about three percent more organic matter than the former, which shows the close similarity between the two, compared to the Humisol which has 10-20% less organic matter than either.

TABLE 22. WATER, ORGANIC MATTER AND ASH CONTENTS OF HUMISOL

Horizon + Profile	August							
	Wet wt. basis % water	Ave.	Oven-dry basis % water	Ave.	Oven-dry peat % O.M.	Ave.	Oven-dry peat % Ash	Ave.
I a*	80.70		418		80.49		19.51	
b	81.43	80.84	438	422	84.86	82.36	15.14	17.64
c	80.40		410		81.73		18.27	
II a	84.17		532		86.03		13.97	
b	83.90	84.17	521	519	83.03	81.74	16.97	18.26
c	84.43		503		76.16		23.84	
III a	86.99		669		84.06		15.94	
b	85.44	85.89	587	611	83.33	83.35	16.67	16.65
c	85.25		578		82.67		17.33	
IV a	81.96		454		74.11		25.89	
b	84.23	82.75	534	482	81.18	77.71	18.82	22.29
c	82.05		457		77.84		22.16	
V a	75.89		315		88.98		11.02	
b	74.06	75.44	286	308	66.43	73.24	33.57	26.76
c	76.37		323		64.31		35.69	

*a, b and c refer to the different profiles at each site

October			
Wet wt. basis % water	Ave.	Oven-dry basis % water	Ave.
80.25		406	
76.25	78.87	321	377
80.12		403	
83.61		510	
82.91	83.66	485	513
84.45		543	
84.38		540	
82.10	82.90	459	487
82.21		462	
87.32		689	
85.94	86.32	611	633
85.71		600	
76.33		322	
74.35	74.80	290	298
73.73		281	

TABLE 23. WATER, ORGANIC MATTER AND ASH CONTENTS OF MESISOL

Horizon + Profile	June Wet wt. basis % water	Ave.	Oven-dry basis % water	Ave.	Oven-dry peat % O.M.	Ave.	Oven-dry peat % Ash	Ave.
I a*	92.10		1165		97.44		2.56	
b	90.86	91.21	994	1043	97.75	97.66	2.25	2.34
c	90.66		971		97.78		2.22	
II a	88.07		738		94.21		5.79	
b	87.82	87.47	721	700	93.33	93.34	6.67	6.66
c	86.51		641		92.48		7.52	
III a	90.79		985		93.68		6.32	
b	91.13	90.60	1028	967	95.56	94.86	4.44	5.14
c	89.88		888		95.33		4.67	
IV a	87.32		689		95.97		4.03	
b	87.27	87.58	686	707	95.28	94.28	4.72	5.72
c	88.16		745		91.60		8.40	
V a	89.21		827		96.30		3.70	
b	89.04	89.04	812	812	97.14	96.07	2.86	3.93
c	88.87		798		94.78		5.22	
VI a	87.57		705		92.86		7.14	
b	87.89	87.08	726	678	92.97	93.08	7.03	6.92
c	85.79		604		93.42		6.58	
VII a	90.29		929		92.63		7.37	
b	90.46	90.43	948	944	91.67	93.74	8.33	6.26
c	90.53		956		96.91		3.02	
VIII a	89.86		886		98.00		2.00	
b	89.12	90.75	819	1039	94.64	95.50	5.36	4.50
c	93.38		1411		93.85		6.15	

*a, b and c refer to the different profiles at each site

September			
Wet wt. basis % water	Ave.	Oven-dry basis % water	Ave.
77.73		349	
75.85	79.62	314	414
85.28		579	
86.30		630	
85.80	86.97	604	676
88.80		793	
89.34		836	
89.16	89.82	822	888
90.95		1005	
87.78		718	
85.11	87.06	572	681
88.30		754	
87.81		720	
89.32	88.95	836	810
89.73		874	
86.13		621	
85.26	85.68	578	599
85.64		597	
88.32		756	
88.58	89.99	775	958
93.06		1342	
88.24		750	
88.31	88.60	755	778
89.25		830	

TABLE 24. WATER, ORGANIC MATTER AND ASH CONTENTS OF FIBRISOL

Horizon + Profile	August Wet wt. basis % water	Ave.	Oven-dry basis % water	Ave.	Oven-dry peat % O.M.	Ave.	Oven-dry peat % Ash	Ave.
I a*	76.40		324		96.19		3.81	
b	76.82	76.57	331	327	100.00	97.93	0.00	2.07
c	76.48		325		97.60		2.40	
II a	84.76		556		96.82		3.18	
b	84.00	84.38	525	540	97.67	97.35	2.33	2.65
c	84.38		540		97.56		2.44	
III a	89.20		826		99.12		0.88	
b	90.12	89.79	912	881	100.00	98.75	0.00	1.25
c	90.05		905		97.12		2.88	
IV a	87.51		701		100.00		0.00	
b	88.58	88.80	775	802	95.76	97.29	4.24	2.71
c	90.30		931		96.12		3.88	
V a	84.28		536		95.12		4.88	
b	81.43	83.37	439	505	94.18	96.01	5.82	3.99
c	84.40		541		98.74		1.26	

*a, b and c refer to the different profiles at each site

Table 25. Soil properties of the three major sites

Bog	Depth	Horizon	pH	WHC	% Saturation	% Fibre	Pyrophosphate Index	Colour	CEC	%N	%C	C/N
Humisol Granada	0 - 6"	L	5.6	9.2	70	86.3	1	2.5YR 8/0	93	1.28	40.8	31.9
	6 - 10"	F/H	5.8	5.8	83	62.0	1	2.5Y 8/1	181	1.17	39.2	33.5
	10 - 13"	L/F	6.3	10.3	86	84.4	1	2.5Y 8/0	174	1.01	39.1	38.8
	13 - 21"	H	5.8	6.9	82	80.2	2	10YR 8/1	195	0.98	39.5	40.4
	21 - 28"	H	5.9	8.2	76	77.7	7	10YR 7/2.5	185	1.10	39.4	35.6
	28 - 34"	H	6.0	4.6	85	52.6	10	10YR 5.5/3	179	1.17	37.4	32.1
	34 - 40"	H	6.1	2.3	83	37.8	10	10YR 5.5/3	162	1.24	30.6	24.7
Mesisol Evansburg	0 - 7"	L	3.6	15.0	18	97.2	1	2.5Y 8/0	130	0.71	41.1	58.2
	7 - 11"	F	3.8	9.9	26	96.1	3	10YR 7/2	98	1.68	43.8	26.0
	11 - 19"	L/F	4.0	15.5	28	85.3	2	10YR 7/1	102	0.96	43.3	45.2
	19 - 31"	F	4.7	10.8	41	80.1	3	10YR 7/1	105	1.69	47.2	28.0
	31 - 42"	F	5.1	7.3	64	76.1	3	10YR 7/2	136	1.38	47.4	34.4
	42 - 52"	F	5.1	13.6	64	80.1	3	10YR 7/1.5	129	0.97	47.5	48.9
Fibrisol	0 - 6"	L	3.5	6.3	18	87.1	1	10YR 8/1	139	0.92	48.0	52.1
	6 - 12"	F	3.0	6.7	17	68.8	5	10YR 6/3	146	1.27	48.7	38.5
	12 - 17"	L	3.5	16.6	17	78.4	6	2.5Y 7/2	160	0.98	46.1	46.9
	17 - 20"	L	3.4	8.1	20	65.7	10	10YR 6/4	147	1.17	42.2	40.3
	20 - 32"	L/F	3.4	8.9	25	75.0	10	10YR 6/4	175	0.92	46.6	50.5
	32 - 38"	L/F	3.7	12.3	24	83.0	10	10YR 6/3	143	0.69	43.2	62.8
	38 - 47"	F	4.1	5.8	37	51.5	4	10YR 6.5/3	123	2.47	50.2	20.3
	47 - 55"	F	4.6	4.6	44	47.1	7	10YR 6/3	121	3.01	48.6	16.2

B. BACTERIAL ANALYSES

1. Soil extract experiments

The following bacterial counts were obtained from the first experiment, using diphosphate and yeast additions to the peat extract:

Table 26. Bacterial counts from peat extract experiment 1.

Medium	Replicates A	B	C	D	E	Ave.
Peat extract	33	18	18	25	13	21.6
SE + phosphate	16	17	19	19	33	20.8
SE + yeast	28	23	20	18	12	20.2
SE + P + Y	14	33	10	14	15	17.2

All colonies were very small, and the numbers were very similar throughout. If anything the addition of diphosphate depressed the counts obtained, which is contrary to the findings of James (1958). In the second experiment using greenhouse soil as well as peat, the results were:

Table 27. Bacterial counts from soil extract experiment 2.

Extract		Amount of Extract Obtained	Plated sample Peat Index of counts	Soil	pH
Peat I	(i)	1100 ml	0.6	7.8	-
	(ii)		8.0	32.8	4.8
	(iii)		1.8	24.2	6.8
Peat II	(i)	1100 ml	0	5.0	-
	(ii)		0.6	4.6	4.8
	(iii)		6.6	18.2	6.8
Peat III	(i)	1125 ml	86	119	-
	(ii)		130	95	4.8
	(iii)		30	112	6.8
Soil I	(i)	825 ml	0	57.6	-
	(ii)		17.6	69	4.8
	(iii)		17.8	78.6	6.8
Soil II	(i)	750 ml	0	144.3	-
	(ii)		140.6	187.2	4.8
	(iii)		79	152	6.8
Soil III	(i)	1100 ml	3.4	26.2	-
	(ii)		5.0	21.8	4.8
	(iii)		6.4	26.6	6.8

The most bacteria from both peat and greenhouse soil grew at pH 4.8 on extract 5, (made from 400 g of greenhouse soil), which was also the most concentrated as the least amount of extract was obtained. This medium gave 140 bacteria, only one quarter of the average count on Plate Count medium. None of the pHs was consistently better for supporting the growth of the greatest number of organisms, and for these reasons the method was discontinued in the present study. There seems to be many more problems to be solved before soil extract can be recommended as superior to other standard media in supporting the largest number of peat micro-organisms.

2. Nutritional study

The numbers of bacteria growing on the four nutritionally different media are shown in Tables 28-32. They are expressed in thousands per gram oven-dry weight. The profiles at each site, and the effect of sampling date are compared.

As Plate Count gave the highest numbers of bacteria, only these figures will be discussed. Definite patterns can be seen in the profiles, notably the large numbers at the surface, presumably because of the supply of oxygen for aerobes. The marked increase of numbers at depth similar to that found by other workers, (for example Waksman and Stevens 1929, Beck and Poschenrieder 1958), could be due to facultative anaerobes, or to the residual spores of Bacilli active in these layers when they were at the surface, or to leaching of bacteria and spores down the profile. A wide range of bacteria is present in the lower horizons, which suggests that residual spores cannot be the only possibility, and leaching is perhaps not so important in a soil containing so

much water. A detailed study of the anaerobic population would be a most useful contribution to understanding this situation.

The general character of the microbiological sequence through the horizons is repeated in each of the three profiles. However the figures do indicate the variability of the material, which in a few cases is substantial.

3. Temperature of incubation

Figures 4-6 indicate respectively the numbers in thousands per gram oven-dry weight, of psychrophilic, mesophilic and thermophilic bacteria present on Plate Count, in these peats at different times of the year. As would be expected there are most mesophiles ($28^{o}C$), except in the Cryic Fibrisol where psychrophiles ($15^{o}C$) are more abundant, especially in the surface horizon. In horizon I and IV of the Mesisol there are a good number of thermophiles, and these appear to be dominant in IV. There are extremely few thermophiles in the Cryic Fibrisol. All three temperature groups for the Humisol show the high surface count, and a further increase in numbers at depth in August for the psychrophiles and mesophiles, with decreased numbers especially at depth in October when ice was present in these lower horizons. Many fewer thermophiles are present, but there seem to be more in the lower part of the profile in October, the reason being unknown.

The psychrophilic and mesophilic counts for the Mesisol are likewise similar to previously reported patterns. Here the numbers are greatest at the surface in September, and at depth in June, this is probably also related to temperature. The thermophiles, again in the least numbers at this site but more numerous than those of either the Humisol or the Fibrisol, exhibit a different pattern. After a rise in

TABLE 28. BACTERIAL NUMBERS. GRANADA HUMISOL AUGUST

Corrected for Moisture

Sub Profile	Horizon	#1 Agar 15°	#1 Agar 28°	#1 Agar 50°	Basal 15°	Basal 28°	Basal 50°
A	I	>1036	>1036	5	>1036	>1036	<1
	II	215	291	13	171	190	<3
	III	131	154	<3	200	100	<3
	IV	449	831	<6	338	443	6
	V	>8300	>3735	17	>8300	>2594	<5
B	I	>1076	>1076	11	>1076	>1345	<<1
	II	267	373	56	211	242	<3
	III	179	254	7	144	199	<3
	IV	>4280	>5389	6	>4470	>5801	<7
	V	>3281	>3474	27	>3281	>2413	<4
C	I	>1020	>1530	5	>1020	>2040	<1
	II	880	1248	42	923	941	<3
	III	407	373	7	434	427	14
	IV	1515	>1448	<6	>1198	>1699	<6
	V	>1015	>3807	13	>2538	>2644	<5

*All bacterial numbers are expressed in thousands per gram oven-dry weight, unless otherwise stated.

B. 12

15°	28°	50°
>1901	3300	<2
272	310	19
146	154	<3
476	604	<6
3237	>10375	17
>1329	4019	11
484	429	12
254	254	34
>1902	767	44
>1042	>7720	112
10674	11985	10
694	1164	<3
278	387	<3
1482	1560	6
>1882	>4230	47

Plate Count

15°	28°	50°
>2264	>2756	207
303	348	<3
162	185	<3
476	593	<6
>4565	>12450	29
>2550	4751	108
509	292	6
302	234	7
>4184	1008	38
>4439	>11580	46
>10200	22012	5
>1260	1242	<3
298	475	14
>1393	2228	6
>2855	5922	59

TABLE 29. BACTERIAL NUMBERS. GRANADA HUMISOL OCTOBER

Sub Profile	Horizon	#1 Agar 15°	#1 Agar 28°	#1 Agar 50°	Basal 15°	Basal 28°	Basal 50°
A	I	>961	>936	<6	466	729	<6
	II	195	482	<7	24	55	<7
	III	>77	211	<7	6	0	<7
	IV	395	79	<80	40	316	<80
	V	127	84	317	<50	<50	<50
B	I	>2652	>2421	4	>842	>1326	<5
	II	>995	685	<6	211	217	29
	III	308	486	6	235	207	<6
	IV	391	<80	<80	107	142	<80
	V	<40	215	20	<40	195	<40
C	I	>1056	>1207	<6	3018	684	<6
	II	>1704	>1415	<7	>643	>514	<7
	III	135	309	<6	6	107	<6
	IV	70	1050	<80	350	385	<80
	V	1105	1410	57	19	172	<50

Plate Count

15°	28°	50°
3036	3163	76
262	238	6
70	141	32
40	395	<80
21	253	295
5473	2737	<50
761	503	<6
224	285	<6
<80	356	<80
<40	195	215
3018	1911	<60
2122	1222	<7
214	388	<6
105	525	<80
1943	610	19

TABLE 30. BACTERIAL NUMBERS. EVANSBURG MESISOL JUNE

Corrected for Moisture

Sub Profile	Horizon	#1 Agar 15°	#1 Agar 28°	#1 Agar 50°	Basal 15°	Basal 28°	Basal 50°
A	I	202	531	<5	354	278	<5
	II	478	545	<3	>670	637	<3
	III	>369	391	<4	282	304	<4
	IV	79	118	<3	126	95	<3
	V	>364	538	<4	241	260	<4
	VI	>1369	1683	<4	1739	1167	<4
	VII	>1533	>2418	<4	>3087	7923	<4
	VIII	>4161	>4457	<4	>2307	>2633	<4
B	I	274	635	<4	208	1105	<4
	II	>328	386	<3	345	304	<3
	III	90	192	<4	23	11	23
	IV	102	47	<3	24	31	<3
	V	>265	821	<4	465	493	<4
	VI	>231	339	<4	578	479	<4
	VII	>3322	>3867	<4	>3375	>1750	<4
	VIII	>2224	>2564	<4	>1627	>1783	<4
C	I	257	364	<4	257	300	<4
	II	>393	652	<3	319	400	<3
	III	79	40	20	30	20	<4
	IV	>355	254	<3	118	254	<3
	V	>108	153	36	90	90	<4
	VI	>472	275	7	345	352	<3
	VII	>2777	>4615	<4	>1669	>1869	<4
	VIII	>5017	>4911	<6	>3022	>2901	<6

B. 12

15°	28°	50°
3542	190	<200
545	7249	5028
<400	<400	<400
<300	<300	<300
-	6257	<400
403	403	<400
8078	2573	3087
3796	1331	1479

Plate Count

15°	28°	50°
443	11132	12650
2162	4316	<300
3960	79748	163
1184	4221	1184
139	11449	3569
523	3341	<400
17493	6174	1029
5571	4585	345

1969	3446	5470
411	8621	<300
<400	2256	5640
393	393	<300
5016	912	9576
<400	<400	<400
2620	3144	524
9190	<400	<400

656	4540	<400
4639	411	<300
<400	2087	1692
<300	118	9039
1961	775	<400
1363	8260	289
4192	5921	<400
4917	32487	1379

1607	5355	5355
4557	2594	1112
4940	9880	5928
296	4648	<300
449	5837	1796
2112	4224	<300
<400	<400	<400
8311	1511	7555

2303	4659	1607
852	3075	741
<400	3458	<400
1563	423	<300
1661	135	<400
3168	1162	2710
>898	>21806	<400
19114	1662	<600

TABLE 31. BACTERIAL NUMBERS. EVANSBURG MESISOL SEPTEMBER

Corrected for Moisture

Sub Profile	Horizon	#1 Agar 15°	#1 Agar 28°	#1 Agar 50°	Basal 15°	Basal 28°	Basal 50°
A	I	>2950	>3960	<2	>3969	>3668	9
	II	>1037	>679	<3	>1205	>3300	<3
	III	-	-	<10	1123	>749	<10
	IV	172	254	<9	57	74	<9
	V	>2460	>3362	<9	>3690	>4920	<9
	VI	>3281	>5047	<8	>4651	>4687	<8
	VII	>3552	>4109	<9	>642	>856	<9
	VIII	>5525	>8075	<9	17	<9	<9
B	I	>2898	>2347	8	>2037	>1851	<2
	II	42	32857	42	-	21	<3
	III	148	461	92	28	18	9
	IV	>3528	>3898	<7	8803	>4805	<7
	V	>2995	>2480	<10	>3838	>3978	<10
	VI	>2373	>4746	<7	>3560	>6441	<7
	VII	>3306	>7438	<9	9	<9	<9
	VIII	>5344	>5985	<9	-	-	-
C	I	>1833	>1664	14	>883	>1134	<3
	II	411	393	9	116	214	<3
	III	785	354	55	88	144	<12
	IV	1050	1136	9	828	342	<9
	V	672	>1997	<10	1461	877	<10
	VI	>4182	>4879	<7	>1987	>4879	<7
	VII	>9013	>12978	14	<15	<15	<15
	VIII	>8835	>9300	<10	-	-	-

B. 12

15°	28°	50°
>1805	>4059	40
1190	-	27
655	1123	<3
278	147	<10
>2255	>3157	<9
>2343	>3425	<9
>2054	>4066	<8
>5313	>5313	<9

Plate Count

15°	28°	50°
2456	>9151	278
>832	>730	29
1778	1404	<3
401	736	8
>3526	>3362	82
>4326	>4506	22
>4580	>4794	43
>5313	>5313	60

>2935	>3726	29
218	134	120
157	92	9
>3226	>3024	329
3164	>4118	<10
>4882	>4238	<7
>3413	>3938	<9
>5216	>5344	<9

>11633	>11215	75
134	70	70
443	157	<10
>672	>3898	954
>2340	>1778	9
>4068	>4238	34
>5031	>5250	<9
<5130	>5130	<9

584	822	48
375	589	71
365	287	22
1110	922	<9
185	117	<10
>1638	>3659	<7
>8652	>8652	188
>6510	>6510	93

1698	2186	224
652	545	9
1149	685	66
>555	641	9
1003	321	10
>4182	>4356	14
>8652	>9013	130
>8835	>6045	465

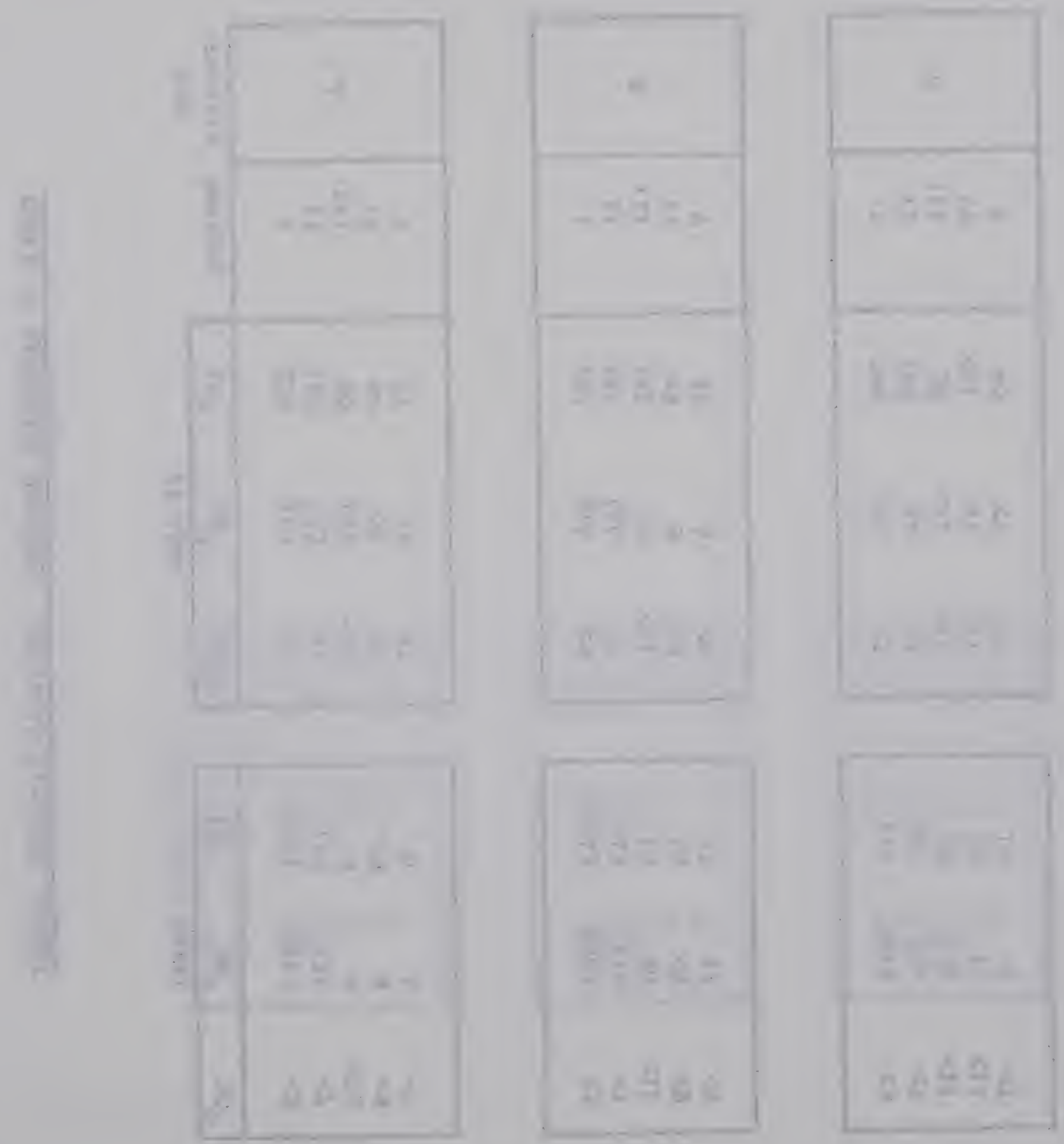


TABLE 32. BACTERIAL NUMBERS. MERIDIAN FIBRISOL AUGUST

Sub Profile	Horizon	#1 Agar 15°	#1 Agar 28°	#1 Agar 50°	Basal 15°	Basal 28°	Basal 50°
A	I	259	115	<5	>191	>763	<5
	II	112	125	<7	112	131	<7
	III	56	102	<10	9	9	<10
	IV	40	56	<9	<9	8	<9
	V	57	32	<7	6	6	<7
B	I	237	216	<5	>345	>582	<5
	II	181	144	<7	319	275	<7
	III	162	10	<11	10	10	<11
	IV	<9	9	<9	44	<9	<9
	V	32	5	<6	27	32	<6
C	I	306	230	<5	174	>616	<5
	II	109	64	<7	205	154	<7
	III	30	<11	<11	10	131	<11
	IV	<11	41	<11	10	10	<11
	V	45	<7	<7	13	6	<7

Plate Count

15°	28°	50°
106	170	<50
413	85	<7
93	139	9
56	168	<9
6	6	<7
1013	194	<50
138	100	<7
253	81	<11
<9	<9	<9
<6	5	<6
786	446	<50
179	83	<7
141	80	<11
113	10	<11
32	39	<7

Figure 4. Bacterial numbers in Humisol

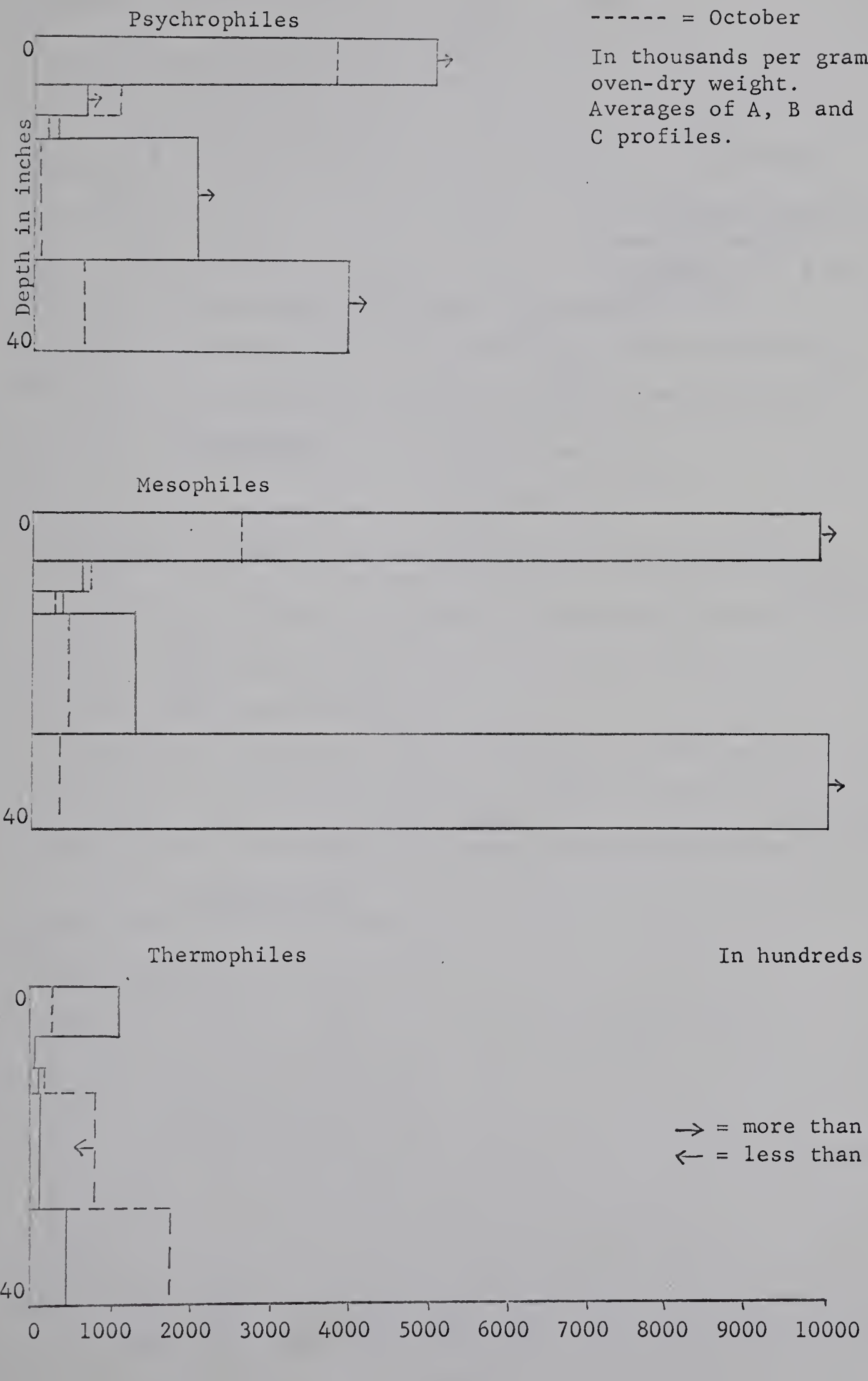


Figure 5. Bacterial numbers in Mesisol

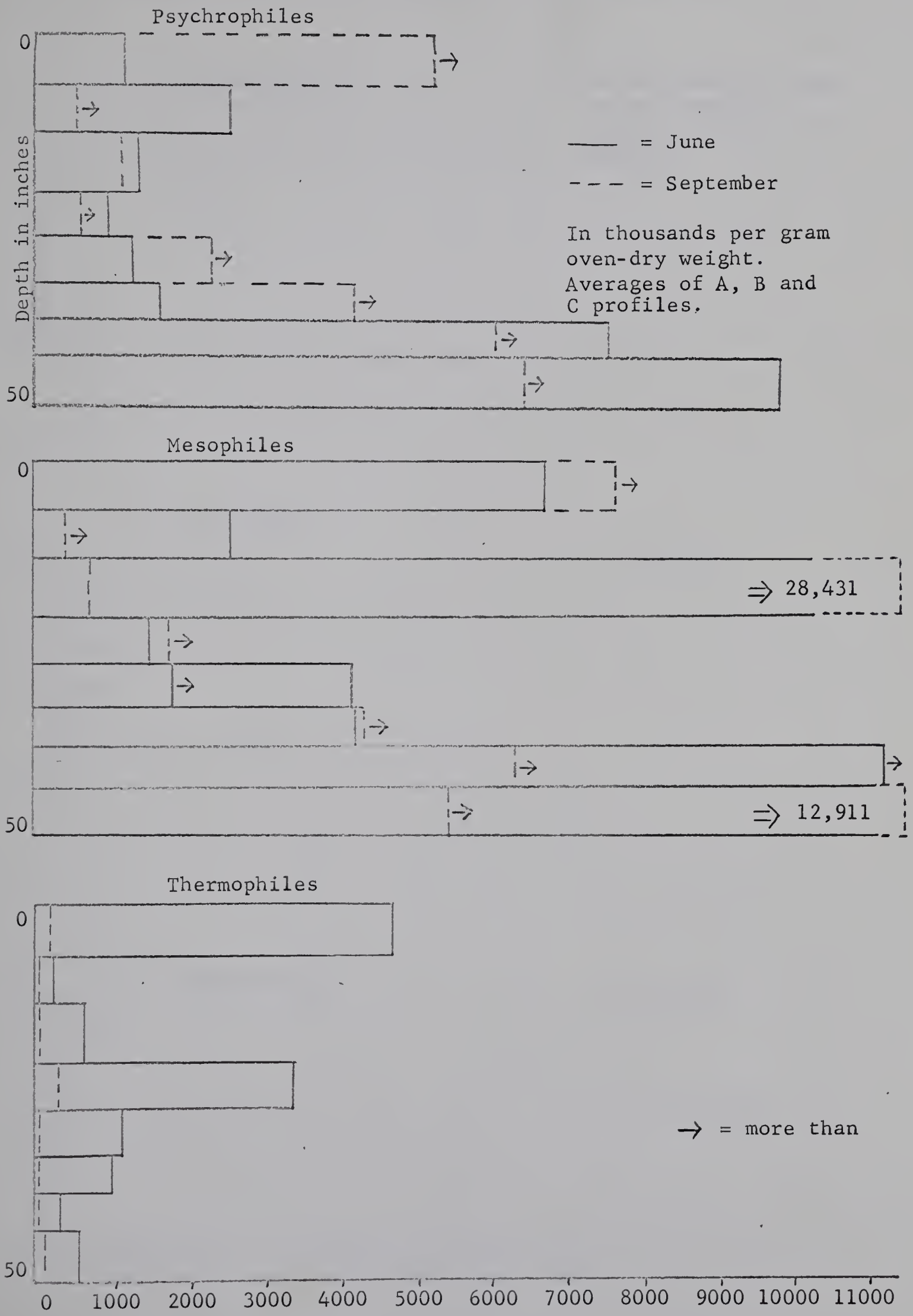
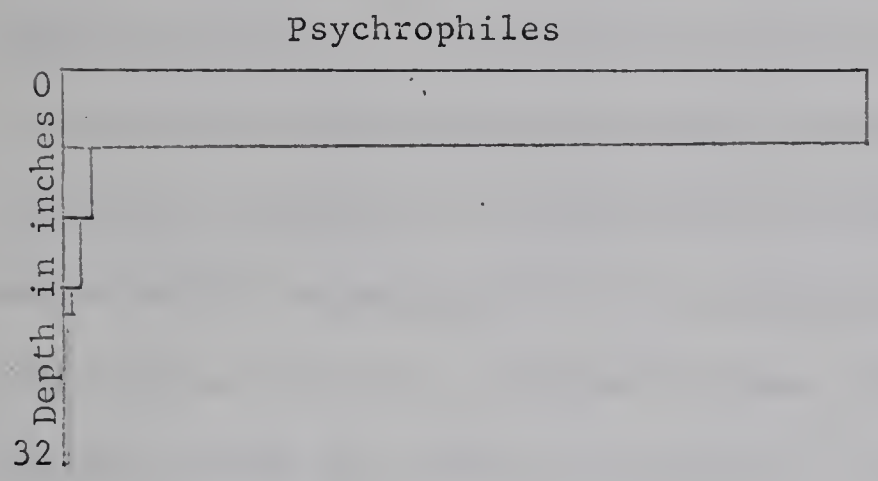
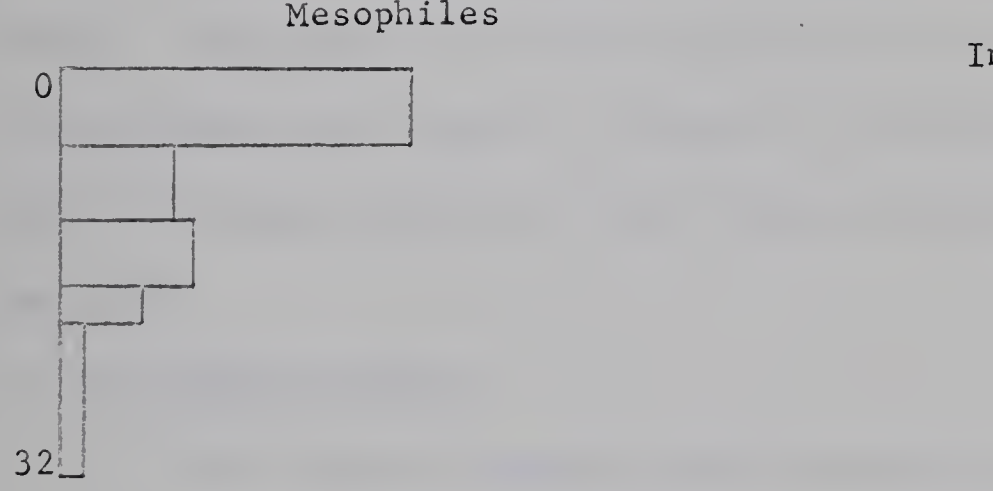


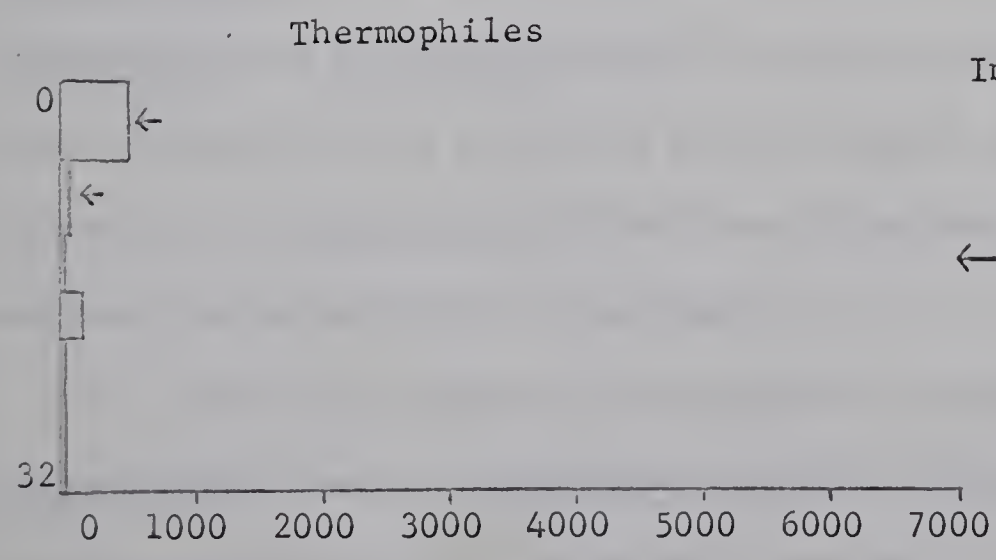
Figure 6. Bacterial numbers in Fibrisol August



In thousands per gram oven-dry weight. Averages of A, B and C profiles.



In hundreds



In hundreds

← = less than

numbers in mid-profile, the counts decrease markedly at depth. An unusual feature of the Mesisol is the extremely high number, over 28 million per gram, of mesophiles in horizon III. A very similar bulge is noted for ammonifiers in the same horizon, (page 107). This layer is unusual because it is loose and relatively undecomposed, with a high water-holding capacity of 15.5, a pyrophosphate index of only 2 and a high C/N ratio (45.2). (Table 25, page 78). Thus it is more like horizon I than any other in the profile. Perhaps the increased bacterial counts are a reflection of increased oxygen content due to the loose nature of the peat; however the fungal counts do not substantiate this.

The Fibrisol has very many fewer bacteria in all temperature ranges. The counts are relatively high in the surface layers and drop off noticeably with depth. The lack of the characteristic increase at depth is thought to be due to the frigid temperatures of this particular bog site.

4. Identification

The range of bacteria found growing on the different nutritional media at the different incubation temperatures can be seen in Tables 33-35 (pages 97-99). Actinomycetes, yeasts, Cytophagae and Chromobacteria are easily recognised, but the identification of Bacillus, Pseudomonas and Arthrobacter had to rely on certain colonial morphological characteristics which are not thoroughly dependable. These should therefore be viewed as tentative identifications, intended only to express the variability of the groups.

The June samples of the Mesisol contained Bacilli, Pseudomonas, Arthrobacter, yeasts, Cytophagae, Nocardia, Micrococcus, Mycobacterium and Chromobacterium. The Fibrisol contained a limited microflora of

Bacilli, pseudomonads, Arthrobacter and yeasts only.

As well as supporting the growth of the greatest number of bacteria, the Plate Count medium also consistently supported the greatest variety of organisms. However this medium did not give the whole range, and in future studies the use of two or more media would be advisable. Generally the psychrophiles are a slightly more varied group than the mesophiles, whilst the thermophiles are mainly restricted to Bacilli and pseudomonads. Of the 67 specimens identified precisely there were 16 Pseudomonas, 13 Bacillus, 13 Cytophaga, 2 Arthrobacter, 1 Acetobacter, 1 yeast and 21 unidentified.

5. Cytophaga

Cytophaga species occurred frequently in the Humisol, occasionally in the Mesisol and not at all in the Fibrisol. Plate 5 shows the appearance of Cytophaga as easily-recognisable bright orange-yellow irregularly shaped colonies on the Plate Count agar. They are especially abundant at the surface of all the peat bogs, and in well-humified layers, (every horizon in the Humisol), and also seem to be restricted by low soil temperatures. They are thought to be strict aerobes (Bergey 1957), but their presence at four feet in a peat bog indicates at least a facultative anaerobiosis. Some idea of the numbers of Cytophagae present in the Humisol is given in Table 36, and the most important morphological characteristics of 12 specimens can be seen in Table 37.

The Cytophagae tested for their ability to utilize cellulose grew on the yeast plates but did not digest the filter paper. Several attempts were made to isolate the extremely rare fruiting myxobacters but none were found. The Myxobacteraceae are very interesting because they feed on other bacteria. This study has shown that they are especially

Table 33. Tentative Identification of Bacterial Types

HUMISOL AUGUST		THERMOPHILES				MESOPHILES							PSYCHROPHILES						
MEDIUM	HORIZON	BACILLUS	PSEUDOMONAS	ARTHROBACTER	ACTINOMYCETE	BACILLUS	PSEUDOMONAS	ARTHROBACTER	ACTINOMYCETE	YEAST	CYTOPHAGA	CHROMOBACTERIUM	BACILLUS	PSEUDOMONAS	ARTHROBACTER	ACTINOMYCETE	YEAST	CYTOPHAGA	CHROMOBACTERIUM
Yeast	I	+	+	+	+	+	+	+			+	+	+			+		+	+
	II	+	+	+		+	+	+			+	+	+	+	+		+	+	+
	III	+				+		+			+	+	+	+	+		+	+	+
	IV	+			+	+		+			+	+	+		+		+	+	+
	V					+					+		+					+	
#1 Agar	I	+	+	+	+	+	+	+			+	+	+					+	+
	II	+				+	+	+	+	+		+	+	+	+		+	+	+
	III	+				+	+	+			+	+	+	+	+				+
	IV	+				+	+	+		+	+	+	+	+	+		+	+	+
	V	+	+			+	+	+			+	+	+	+	+				+
Basal	I	+				+	+				+		+		+			+	+
	II					+		+			+	+	+		+			+	+
	III					+		+			+		+		+		+	+	+
	IV					+		+			+	+	+		+			+	
	V					+		+		+	+		+		+		+	+	+
B. 12	I	+	+			+	+	+			+		+	+	+			+	
	II	+	+	+		+	+	+					+	+	+	+	+		+
	III					+	+	+		+			+	+	+				+
	IV					+	+	+		+			+	+	+				
	V					+	+	+					+	+	+				
Plate Count	I	+	+		+	+	+	+			+	+	+	+	+			+	+
	II	+	+			+	+	+		+	+	+	+	+	+	+	+		+
	III		+			+	+	+		+	+	+	+	+	+		+		
	IV		+			+	+	+					+	+	+			+	+
	V	+				+	+	+				+	+	+	+	+	+	+	+

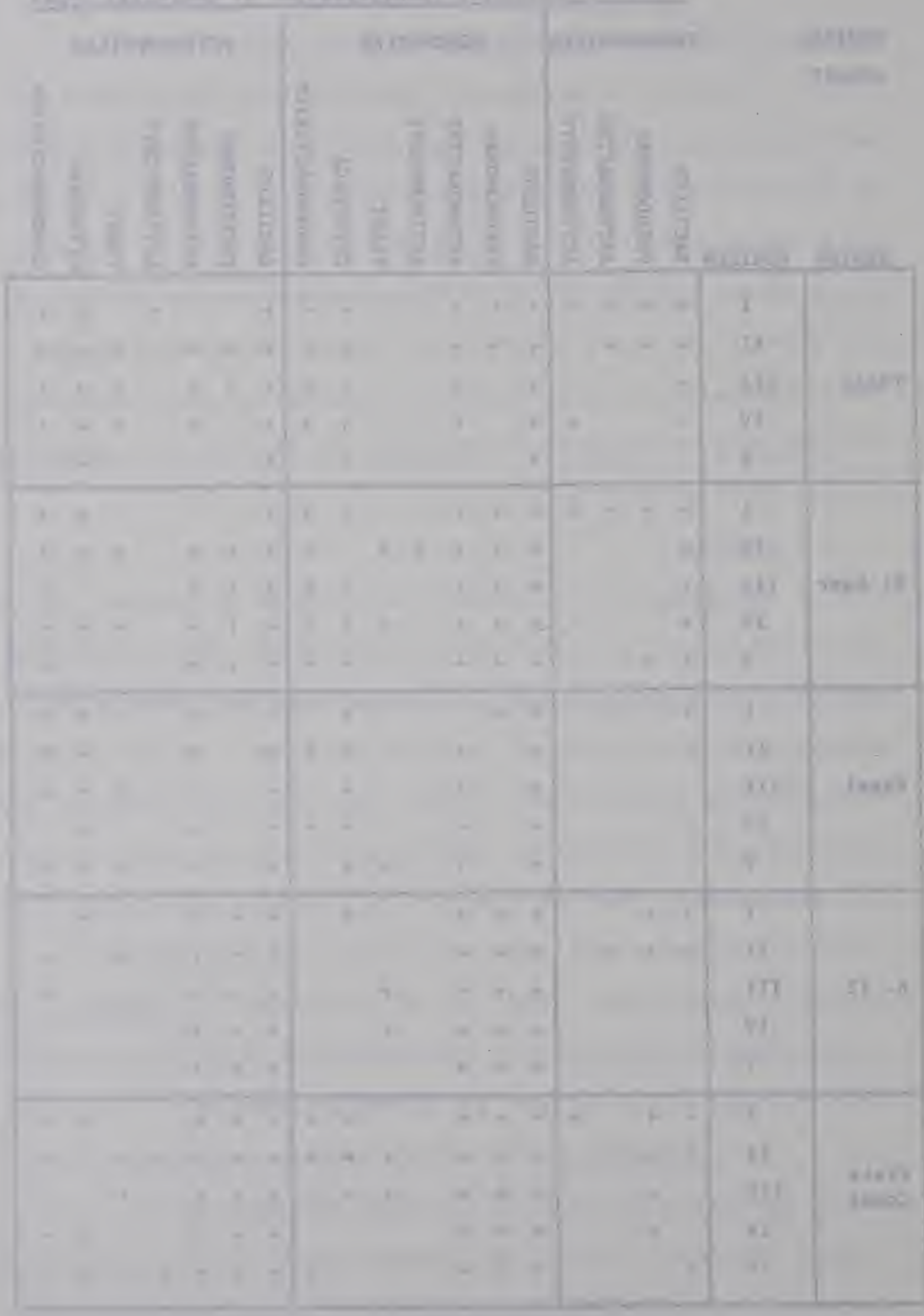


Table 34. Tentative Identification of Bacterial Types

HUMISOL OCTOBER		THERMOPHILES		MESOPHILES						PSYCHROPHILES					
MEDIUM	HORIZON	BACILLUS	PSEUDOMONAS	BACILLUS	PSEUDOMONAS	ARTHROBACTER	YEAST	CYTOPHAGA	CHROMOBACTERIUM	BACILLUS	PSEUDOMONAS	ARTHROBACTER	YEAST	CYTOPHAGA	CHROMOBACTERIUM
#1 Agar	I	+		+	+	+		+	+	+	+	+		+	+
	II			+	+	+		+	+	+	+		+	+	+
	III	+		+		+	+	+	+	+				+	+
	IV			+						+				+	
	V	+		+		+		+		+		+		+	
Basal	I			+		+				+		+		+	+
	II			+		+		+		+		+		+	
	III			+						+		+			+
	IV	+		+						+					
	V			+		+				+					
Plate Count	I	+	+	+	+	+		+	+	+	+	+		+	
	II	+		+		+		+	+	+	+	+	+	+	
	III	+		+		+		+		+	+	+		+	+
	IV			+		+				+		+			
	V	+	+	+		+				+		+		+	

Table 35. Tentative Identification of Bacterial Types

MESISOL SEPTEMBER		THERMOPHILES					MESOPHILES						PSYCHROPHILES					
MEDIUM	HORIZON	BACILLUS	PSEUDOMONAS	ARTHROBACTER	YEAST	ACTINOMYCETE	BACILLUS	PSEUDOMONAS	ARTHROBACTER	YEAST	CYTOPHAGA	CHROMOBACTERIUM	BACILLUS	PSEUDOMONAS	ARTHROBACTER	YEAST	CYTOPHAGA	CHROMOBACTERIUM
#1 Agar	I	+					+	+	+		+		+	+	+	+	+	+
	II	+					+		+				+		+	+	+	
	III	+					+			+			+		+	+		
	IV	+					+	+	+	+			+	+				
	V						+			+			+	+		+		
	VI						+	+					+	+				
	VII	+					+	+				+	+	+				+
	VIII						+	+					+	+				
Basal	I	+					+	+	+				+	+	+			
	II						+		+				+	+				
	III	+					+	+					+					
	IV						+						+		+			
	V						+						+	+		+		
	VI						+	+					+					
	VII						+						+					
	VIII												+					
B. 12	I	+	+				+	+	+	+			+	+	+	+		
	II	+	+				+	+	+	+			+	+	+	+		
	III	+	+				+	+		+			+	+	+	+		
	IV	+					+	+	+	+				+				
	V	+					+	+		+			+	+	+	+		
	VI						+	+						+		+		
	VII						+	+					+	+		+		
	VIII							+					+	+		+		
Plate Count	I	+	+				+	+	+	+	+		+	+	+	+	+	+
	II	+	+	+		+	+	+		+			+	+	+	+		
	III	+	+				+	+	+	+			+	+	+	+		
	IV	+					+	+	+	+			+	+	+	+		
	V	+					+	+	+	+			+	+	+	+		
	VI		+		+		+	+		+			+	+				
	VII	+	+				+	+				+	+	+	+			+
	VIII	+	+				+	+					+	+				

Plate 6. Cytophagae present in surface horizons of Mesisol growing on Plate Count agar

Table 36. Thousands of Cytophaga in Humisol

	August samples		October samples	
Horizon	15°C	28°C	15°C	28°C
I	658	1139	159	59
II	20	20	195	224
III	<8	2	15	13
IV	62	11	<80	<80
V	7	<5	25	13

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

abundant in well-decomposed peat horizons. Further work on their role in this situation would be worthwhile.

Table 37. Characteristics of some Cytophagae from a Mesisol

Colour on Plate Count	Action on NO_3	Action on NO_2	Wet mount morphology Shape	Size in μ	Lysis on yeast*	Spreading on yeast	#1*
Gold	-	-	rod	1 x 10-15	2	3	3
Gold	-	-	rod	1 x 10-15	2	3	3
Lemon	-	trace	rod	1-1.5 x 5-10	0	1	2
Gold	-	-	rod	1.5 x 5	3	2	1
Yellow	-	-	rod	1.5 x 8	0	1	1
Gold	-	-	rod	1 x 10-20	2	4	4
Bright yellow	-	-	rod	1.5 x 2	0	2	2
Gold	-	-	rod	1 x 3-10	3	2	1
Yellow	-	-	rod	1 x .5-1.5	2	3	4
Yellow	-	-	rod	1 x 5-15	1	3	3
Yellow	-	-	?	?	0	1	2
Yellow	-	-	rod	1 x 3-5	0	1	1

*radius measured in mm.

6. Chromobacterium

Species of Chromobacterium are most plentiful in the Humisol, and the counts are shown in Table 38. The purple to cream leathery colony growth is characteristic and 20 specimens suspected of belonging to this genus were isolated for a special study, the results of which follow.

Table 38. Thousands of Chromobacterium in Humisol

Horizon	August samples 15°C	August samples 28°C	October samples 15°C	October samples 28°C
I	23	49	<50	7
II	182	95	4	8
III	5	<8	4	28
IV	27	<7	<100	<100
V	76	<5	<70	<70

Microscopical examination and gram-staining indicated that eight of the 20 were gram-negative rods, therefore only these will be considered now. Two of these were eliminated by their inability to produce purple pigment on standard media. The remaining six all grew best at 23°C, two also grew at 3.5°C, and four at both 3.5° and 37°C, thus repudiating one of Bergey's (1957) suggestions. All six grew and produced violacein best on a simple tryptone agar (#1 medium, see Appendix I). They liquefied gelatin and produced acid from glucose. Five reduced nitrate to nitrite, but none reduced iron. Five were classified as variants of C. violaceum and one was probably C. amethystinum. Four characteristics were observed which were at least as good, if not better than those given by Bergey (1957) for distinguishing the genus. These were the mucoid nature of the colony, its convex to pulvinate shape, the circular entire edge of the colony, and the ability to grow best on a simple tryptone agar.

The presence of the genus Chromobacterium in the more humified horizons suggests a need for substances released by the action of other bacteria on the organic matter. Their ability to grow best in the laboratory on tryptone indicates that their nutritional needs are simple. Perhaps they rely on simple proteins and carbohydrates which may only be available when the peat material has been considerably broken down by other microbial action.

C. FUNGAL ANALYSES

1. Enumeration

A comparison of figures obtained from Rose Bengal and Potato dextrose pour plates (Table 39), indicates the consistent superiority of the Rose Bengal medium for total counts. The individual fungi on

this medium were moreover restricted in size, and these discrete colonies were much easier to count than those on Potato dextrose plates. The variability between the A, B and C profiles at the three sites was small. Only psychrophilic and mesophilic fungi have been enumerated, and although the counts are very, very similar there seems to be slightly more psychrophiles in the Mesisol, and a few more mesophiles in the Fibrisol. An experimental run on the Mesisol samples in September indicated very few fungi able to grow at 50°C.

Horizon	Thousands of thermophilic fungi
I	<6
II	<1
III	<2
IV	<1
V	<0.5 (One fungus)
VI	<1
VII	<0.5 (Two fungi)
VIII	<1

The colonies found were extremely small and might possibly have been contaminants.

Fungi are mostly strict aerobes and their virtual restriction to the surface horizons denotes this fact. In the Humisol only the top 10" have significant numbers, where the pH is less than 5.8 (see Table 25 page 78). In the horizon below this the pH is 6.3 and this may restrict the growth of fungi. The Mesisol has a good number of fungi down to 21", and although it is less aerobic than the Humisol at this depth, the pH is around 4.0. The Fibrisol has few fungi below 12", yet its water content and degree of decomposition are roughly the same as those of the Mesisol, and its pH is slightly more acid. Some other factor, perhaps the low temperature, is restricting survival in the lower layers here. The fungal counts recorded for the lowest horizons probably result from

the persistence of resistant spores, (but see "Immersion tubes'). The maximum number of fungi are seen to be present in the soils' warmest period of August to September, at all sites.

Table 39. Psycrophilic and Mesophilic Fungi*

Granada Humisol

Horizon	August Mesophiles RB	August Mesophiles PDA	October Mesophiles RB	October Mesophiles PDA	October Psychrophiles RB	October Psychrophiles PDA
I	269	267	92	30	31	17
II	21	22	13	2	11	2
III	<1	1	1	1	<1	<1
IV	<1	1	<1	<1	<1	<1
V	<1	2	<1	<1	<1	<1

Evansburg Mesisol

Horizon	June Mesophiles RB	June Mesophiles PDA	September Mesophiles RB	September Mesophiles PDA	September Psychrophiles RB	September Psychrophiles PDA
I	269	185	379	279	584	241
II	198	163	66	24	84	59
III	9	4	64	43	67	28
IV	6	1	5	2	5	7
V	3	2	3	1	<1	2
VI	<1	41	<1	1	1	1
VII	<2	2	2	4	2	2
VIII	2	2	<1	<1	1	<1

Meridian Fibrisol

Horizon	August Mesophiles RB	August Mesophiles PDA	August Psychrophiles RB	August Psychrophiles PDA
I	372	220	174	178
II	35	37	33	16
III	5	4	1	3
IV	1	1	<1	<1
V	1	5	<1	9

*In thousands, to nearest thousand, per gram oven-dry weight.

2. Identification

Of the 57 specimens sent for generic identification, 37% were Penicillia and there were four Chrysosporia, two Cladosporia, one Gelasinospora, one Phialophora, one Mucor ramannianus (grey variant) and one yeast. Penicillia probably made up about 75% of the total population on the Rose Bengal plates. This preponderance is in agreement with, among others, Christenson and Whittingham (1965), who also report Chrysosporium and yeasts from Wisconsin peat bogs. The genus Cladosporium was reported from similar areas by Dahman and Ramant in 1954 and by Kuster in 1963.

3. Immersion tubes

The following numbers of actively growing fungi were found:

Table 40. Fungal numbers from immersion tubes

Site	Horizon	Horizontally cut Depth	#	Longitudinally cut Depth	#
Granada Humisol	I	2.5"	0	4"	0
	II	6"	4	8"	1
	III	10"	1	15"	2
		21"	3		
	IV	31"	4	29"	5
				35"	1
Evansburg Mesisol	I	2.5"	2	4.5"	2
	II	7"	3	9"	3
	III	10.5"	5	12.5"	3
	IV	15.5"	6	18.5"	3
	V	21.5"	4		
	VI	28.5"	1	25"	4
	VII	33.5"	5	32"	1

Generally the immersion tube agar which was separated into eight horizontal slices gave a larger number and more types of fungi than the longitudinally-sliced ones, because of the lack of overcrowding. The

types of fungi isolated were very similar to those observed in the plate method.

This method did show the presence of actively growing filaments in all the horizons of both types of peat examined. Even if these were spores stimulated to germinate by the presence of the agar, it still proves that fungi are capable of surviving in anaerobic conditions at depth in these peats.

D. PHYSIOLOGICAL STUDIES

There were no positive tubes at all in the tests for nitrification and nitrogen-fixation. Only the first stage of denitrification took place with the following numbers of organisms active:

Table 41. Denitrifiers in thousands per gram oven-dry weight

	Humisol		Mesisol		Fibrisol
Horizon	August	October	June	September	August
I	839	20	6	-	3
II	6320	610	1089	25	5
III	7690	5	378	51	3
IV	5540	19	28	818	1
V	7	2	-	820	0
VI	-	-	-	721	-
VII	-	-	-	15	-
VIII	-	-	-	6	-

Organisms possessing the ability to convert nitrate to nitrite occur in much greater numbers in the second and third horizons than in the surface layers, and there are far fewer in the frigid Fibrisol. Greater potential activity is apparent in the June and August samples of the Mesisol and Humisol respectively, than from the samples taken late in the season.

Bacteria capable of effecting ammonification of plant protein were present in significant numbers.

Table 42. Ammonifiers in thousands per gram oven-dry weight

	Humisol		Mesisol		Fibrisol
Horizon	August	October	June	September	August
I	34,557	-	280	3,143	10
II	61,867	-	769	2,401	16
III	71,133	128	100,500	637	7
IV	38,316	615	275	164	4
V	41,800	190	-	1,049	8
VI	-	-	-	1,666	-

In the Humisol there are a high number of ammonifiers all through the profile in the middle of the season, and these decrease by October. The early sample of the Mesisol shows the bulge of 100 million ammonifiers per gram in horizon III. This increase was noted before on Plate Count medium, when it was related to the loose relatively undecomposed nature of the material, its high water-holding capacity and high C/N ratio. This is however, four times the number of bacteria found in the horizon by the best agar medium, showing that the latter only supports a fraction of the soil micro-organisms, notably the aerobes. At least three quarters of the population must be anaerobic. The Fibrisol is again noteworthy for having very few ammonifying bacteria.

The MPN counts for bacteria capable of iron reduction are shown in Table 43. There does not seem to be any consistent pattern in their distribution, and the numbers are generally higher than for mineral soils. In the latter a range of 10,000 to 100,000 is common for A horizons, the number seeming to increase with the content of organic matter and water.

Table 43. Thousands of iron reducers per gram oven-dry weight

Horizon	Humisol		Mesisol	
	August	October	June	September
I	17,326	49	298	117
II	56	71	738	474
III	26	25	50	94
IV	285	15	33	781
V	1,820	11	20	105
VI	-	-	15	21
VII	-	-	8	529
VIII	-	-	2	295

E. OTHER MICROBIAL ANALYSES

1. Actinomycetes

Actinomycetes occur very rarely, due to the acidity of peat areas. In the Humisol only one or two were found in each horizon, in the Mesisol 21 thousand per gram occurred in horizon I, with only 8 thousand in horizon II and none deeper. Forty-two thousand were present at the surface of the Fibrisol, and this number dropped to 27 thousand in the frozen horizon IV. The results are somewhat surprising in that more Actinomycetes were found in the more acid environments.

2. Algae

Green algal growth was noted in a few of the tubes of Bristol's solution from the Mesisol samples but fewer than two thousand per gram oven-dry weight were present in horizons I to III. Euglenoids, Chlorococcum-types and members of the Ulotrichaceae were observed.

3. Myxomycetes

None were observed, possibly because the peat is both too acid and too wet for their survival.

4. Contact slides

The results of observations on these slides were disappointing.

Fungal mycelia were noted in the top 5" of both Humisol and Mesisol, and filamentous algae at 3" in the Humisol. It is thought that either their incubation time in the soil was not long enough or perhaps the slides were allowed to dry too thoroughly before observations were made.

5. Antibiotic study

Without dilution of the supernatant, a zone of inhibition 2 mm in diameter was measured. This is a very small effect, thus it may be a lytic enzyme, but it is not an antibiotic.

SUMMARY AND CONCLUSIONS

The purpose of this project was to characterise certain Alberta peat bogs pedologically, botanically and microbiologically, in order to discover more about the natural conditions in which the Myxobacterales live.

A few microbiological studies have been carried out on peat bogs in various parts of the world, but this is believed to be the first instance that such a study has been performed in Canada. It is also believed to be one of the first attempts to correlate vegetation, soil and microbiological characteristics of peat areas. This may, therefore be regarded as a preliminary study in the relationships between flora, soil and micro-organisms.

Some of the major conclusions of this study include:

1. Specific associations of mosses and higher plants occur on different types of peat bogs. The seral succession of these plant associations is directly related to the development of a particular peat profile.

2. Modifications to the present classification of Canadian peat bogs, based on both the vegetation and chemical and physical properties have been made, and these result in the following revised grouping of more significantly related types of peat bogs:

	Vegetation grouping	Soil Survey nomenclature
Group I	Black Spruce - Sphagnum	Fibrisols and Fibric Mesisols
Group II	Black Spruce - "Feathermosses"	Mesisols and Humisols (excluding sedge bogs)
Group III	Sedges	Some Mesisols and Humisols

3. Relatively large numbers of bacteria and fungi occur in the surface horizons presumably due to the proliferation of aerobes. The marked increase of bacterial numbers at depth, similar to that obtained by other workers, is attributed to facultative anaerobes. However, low temperatures considerably depress the counts.

4. Myxobacters, especially members of the Cytophagaceae, are particularly numerous in the more humified horizons, and may comprise up to one tenth of the population surviving on Plate Count in the Humisol.

5. Species of Chromobacterium are also especially abundant in the well-decomposed layers. Their presence here may be correlated with their need for simple proteins and carbohydrates which may only be available when the peat material has been considerably broken down by other microbial action.

6. The only significant transformation of the nitrogen cycle is ammonification, and up to 100 million bacteria per gram oven-dry weight are active in the breakdown of plant protein in Humisols and Mesisols, with far fewer in the Cryic Fibrisol.

7. Iron reducing bacteria are very common in peat bogs, with up to 170 times as many organisms as in mineral A horizons.

The results of this study have enlarged the knowledge and understanding of peat bogs in Alberta. It is now known that these bogs are somewhat similar to more southerly ones, and that frigid temperatures, although significantly lowering the numbers of active micro-organisms, do not guarantee sterility. The results further show the existence in considerable numbers of certain special groups of

bacteria. However there is still so much to be learned about these areas, that it is difficult to know which of the innumerable problems to attack first.

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APPENDIX I MEDIA

1. #1 Broth and agar

Tryptone	2.0 g
Water	1000 ml
For agar medium add	
Agar	10 g

2. Plate count agar

Tryptone	5.0 g
Yeast extract	2.5 g
Glucose	1.0 g
Agar	15.0 g
Water	1000 ml

3. Basal Broth and agar

Glucose	1.0 g
K_2HPO_4	1.0 g
KNO_3	0.5 g
$MgSO_4$	0.2 g
$CaCl_2$	0.1 g
NaCl	0.1 g
$FeCl_3$	0.01 g
Water	1000 ml
Heat to 100°C, filter after cooling.	
Adjust to pH 6.8	
For agar medium add	
Agar	15 g

4. B12 Broth and agar

K_2HPO_4	0.8 g
KH_2PO_4	0.2 g
$MgSO_4$	0.2 g
NaCl	0.2 g
$FeSO_4$	trace
$MnSO_4$	trace
NaMoO	trace
$CaSO_4$ (v/v sat. sol'n.)	10 ml
Yeast extract	5.0 g
Peptone	5.0 g
KNO_3	3.0 g
Vit. B12 (1 gamma/ml)	2 ml
Water	1000 ml
pH adjusted to 7.0	
For agar medium add	
Agar	15.0 g

5. Yeast agar

Granular yeast	5.0 g
Agar	15.0 g
Water	1000 ml

6. Nutrient Broth and agar

Beef extract	3.0 g
Peptone	5.0 g
Water	1000 ml
For agar medium add	
Agar	15 g

7. Nutrient gelatin

Beef extract	3.0 g
Peptone	5.0 g
Gelatin	120 g
Water	1000 ml

8. Glucose agar

$NH_4H_2PO_4$	0.5 g
K_2HPO_4	0.5 g
Yeast extract	0.5 g
Agar	5.0 g

Bromothymol blue and adjust to pH 7.2
Sterilised glucose added at .5% w/v

9. Rose Bengal-Streptomycin agar

Glucose	10.0 g
Peptone	5.0 g
KH_2PO_4	1.0 g
$MgSO_4.7H_2O$	0.5 g
Agar	15 g
Rose Bengal	33 mg
Water	1000 ml

Sterilise, and when cool enough to pour add Streptomycin to give final concentration of 30 µg/ml.

10. Potato-dextrose (glucose) - Novobiocin

(Novobiocin = albamycin = streptonivicin)

Potatoes, infusion from	200 g	} hydrated medium
Glucose	20 g	
Agar	15 g	

To rehydrate 39 g is suspended in 1000 ml water

Novobiocin (5000 µg/ml)	20 ml

Then autoclave and pour

11. Medium A for Nitrosomonas

NaCl	0.6 g
$MgSO_4$	0.28 g
$FeSO_4$	0.06 g
$(NH_4)_2SO_4$	1.32 g

Dissolve in 180 mls water. Add 20 mls boiled 0.1M KH_2PO_4
Dilute 1:10, dispense. Add excess of $CaCO_3$ to each flask.

12. Medium B for Nitrobacter

NaCl	0.6 g
$MgSO_4$	0.28 g
$FeSO_4$	0.06 g
$NaNO_2$	1.0 g
$NaHCO_3$	0.2 g

Dissolve in 180 mls water. Add 20 mls boiled 0.1M KH_2PO_4.

13. Nitrogen-free Mannitol broth

K_2HPO_4	0.5 g
$MgSO_4$	0.2 g
NaCl	0.2 g
$MnSO_4$	trace
$FeCl_3$	trace
Mannitol $C_6H_8(OH)_6$	5.0 g
Sucrose	5.0 g
$CaCO_3$	3.0 g
Water	1000 ml

14. B10 Broth

K_2HPO_4	0.8 g
KH_2PO_4	0.2 g
$MgSO_4$	0.2 g
NaCl	0.2 g
$MnSO_4$	trace
Na_2MoO_4	trace
$CaSO_4$ (sat. sol'n.)	10 ml
Yeast extract	5.0 g
Peptone	5.0 g
Ferric phosphate	4.7 g
Water	1000 ml

Adjust to pH 7.0

15. Egg Albumen agar

Egg Albumen 0.15 g Dissolved in water and made neutral to phenolphthalein with $\frac{N}{10}$ NaOH

Glucose	10.0 g
K_2HPO_4	0.5 g
$MgSO_4.7H_2O$	0.2 g
$Fe_2(SO_4)_3$	trace
Agar	15 g
Water	1000 ml

16. Bristol's solution (modified)

$NaNO_3$	0.25 g
$CaCl_2$	0.025 g
$MgSO_4.7H_2O$	0.075 g
K_2HPO_4	0.075 g
NaCl	0.025 g
$FeCl_3$	0.5 mg
Water	1000 ml

17. Chu's solution

K_2HPO_4	0.01 g
$MgSO_4.7H_2O$	0.025 g
Na_2CO_3	0.02 g
Na_2SiO_3	0.025 g
Ferric citrate	3.0 mg
Citric acid	3.0 mg
Water	1000 ml